# The U.S. Coast Guard 87’ Patrol Boat Maintenance Program:

# An Analysis of a Scheduling and Resource Leveling Problem

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**Abstract**

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Planning and managing military ship repair projects require a delicate balance between software-based scheduling, resource loading, and risk mitigation strategies. The U.S. Coast Guard Industrial Yard, through use of Oracle’s Primavera software, has historically used the Critical Path Method (CPM) of scheduling for their maintenance projects. With the introduction of an assembly line program to repair all East Coast 87-foot Patrol Boats named the Bow to Stern Program, the Yard resorted to manually sequencing work items using a Work Breakdown Structure. In this paper, spreadsheet modeling is used as an inexpensive and available tool to study concurrent project loading and the benefits of level loading job shops. The results show imminent program challenges with a compressed project timeline and shared resources throughout the shipyard. A decision tree for schedule risk mitigation strategies and a prioritized list of efficiency improvements are created, highlighting the need for labor fatigue studies and an Integrated Master Plan for overall organizational success.


Key Words: Critical Path Method, Ship Maintenance/Construction, Concurrent Projects, Scheduling, Schedule Risk Mitigation Strategies, Level Loading

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# DEDICATION

To my husband, Joshua, for being my rock.

To my children, Liliana and Natalia, for sacrificing time away from your Mother.

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Chapter 1

# INTRODUCTION

## 1.1 Coast Guard Program Details

The United States Coast Guard Industrial Shipyard (CG Yard), located in Baltimore, MD, is the Coast Guard's only in-house depot level maintenance facility in the United States. The CG Yard has a highly skilled workforce that is capable of working on all Coast Guard surface assets less than 378 feet. The facility, composed of an unionized civilian workforce and an active duty support network, tends to be inflexible to major changes, but can take on risky projects that would be unwise to award to commercial shipyards. Some of those risky projects include new technology installations for prototyping, service life extension and mission effectiveness projects, as well as assembly-line maintenance programs utilizing different management strategies.

The CG Yard began a four-year, $49 million depot level maintenance initiative for its 87' Coastal Patrol Boat fleet in November of 2014 called the 87' "Bow-to-Stern" Dry-Dock Program (Coast Guard Yard News 2014). The program will cycle all Atlantic Area 87' patrol boats (WPBs) through the CG Yard instead of awarding individual contracts to commercial shipyards along the East Coast (Figure 1.1.1).

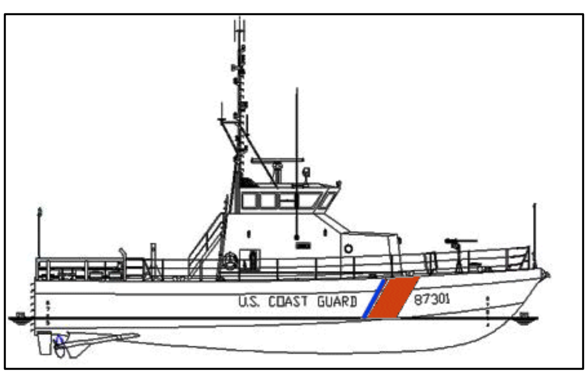



**Figure 1.1.1 87' WPB Drawing of First Cutter in Class and Cutter Underway.**

A different cutter (Coast Guard ship) will arrive at the CG Yard every 30 days for a 60-day maintenance period, called an availability. The availability will consist of a drydock, dockside work, and trials prior to acceptance. The proposed advantages of this project are numerous and include operational, financial, and trade-specific benefits. Operationally, the Coast Guard will use the project to strengthen the predictability of fleet schedules by reducing a 10 ½ -week maintenance schedule into 60 days. Crews that would normally remain with their cutter during repair resulting in reduced operational hours will receive a replacement cutter to bring back to their homeport to continue their mission. Financially, the Coast Guard predicts it will save $2.2 million annually over the life of the project by keeping the business "in-house". Other advantages to using the same facility/workforce include predictable work schedules, optimized task scheduling within trades, and improved processing times through ship familiarity and learning curve.

The 87' Coastal Patrol Boat Marine Protector Class cutters are some of the newest ships in the Coast Guard fleet. They have been in service (commissioned) from 1998 to the present. There are currently 49 cutters on the East Coast of the United States (including Puerto Rico) and 24 cutters on the West Coast (including Hawaii) (U.S. Coast Guard 2015). The names and locations of the cutters can be found in the Appendix (Table A.1). The missions and duties of the Marine Protector Class include Maritime Law Enforcement, National Security, and Safety Patrols. Coast Guard cutters have four-year recurring maintenance cycles where major, depot-level work is conducted at a qualified shipyard.

The "Bow-to-Stern" program will address the most operationally degrading maintenance items via a standard work item package consisting of 37 individual work items. Differences in cutters will be addressed with added work requests. In order to accommodate multiple shifts and seasonal weather fluctuations, two temporary scaffolding systems capable of fully containing one 87’ WPB each will remain erected for the four-year project to provide a climate and humidity controlled environment with proper ventilation, heating, and lighting for parallel work. The program is unique because this class of cutter is relatively small in size, uniform in their configurations, and there are a large number available to mimic an assembly line maintenance program.

Coast Guard project scheduling uses the Critical Path Method (CPM). The typical planning process for a CG Yard availability begins with a specification detailing the work items to be completed in the project. The work items are broken down into broad level tasks and organized into a Work Breakdown Structure (WBS). The WBS is a high level outline of the sequencing of tasks and is more of a hierarchical guideline than a schedule. During this same time, estimators look at similar task estimates to determine the quantity of resources needed for the project. These resources include man-hours for each specific job shop, materials, and support services. The CG Yard then puts specific task line items and their estimated resource needs into the scheduling software. The CG Yard uses Oracle’s Primavera P6™ software for their CPM based scheduling. The version of Primavera (iteration 6) being used by the CG Yard is not user friendly, is outdated, and does not include an Integrated Master Plan (IMP) where schedulers can see the impacts of schedule overrun on other projects (B.L. Melvin, personal communication-email/phone conversation March 31, 2014). These limitations, coupled with new management practices, make risk assessment difficult and often result in schedule extensions for lower priority cutters. Priority sequencing is usually politically based, meaning that the cutter whose mission is of higher importance at that specific time will get the required resources or overloaded resources to speed up project completion.

### 1.2 Study Goals

The goals of this study are three-fold. First, the estimated required labor (in man-hours) will be used to develop spreadsheet models of the program. These will be used to determine if the CG Yard has allocated enough resources to levelly load the project with up to three ships working in parallel. The results of this analysis will be used to provide appropriate mitigation strategies to increase the probability that each availability remains on schedule and on budget. The second goal of the study is to conduct a level-loading study of a single job shop to see how overtime and overmanning can be minimized to reduce overall project resources. Finally, several efficiency improvement tools will be proposed for the CG Yard derived from the results of the first two objectives and prioritized according to implementation feasibility for the organization.

# CHAPTER 2

# BACKGROUND

## 2.1 Literature Review

Due to the broad scope of this project, several different areas of interest will be considered in the literature review. A brief history of scheduling with special emphasis on the CPM in the military will be discussed followed by the methods available for solving extensions of the CPM with concurrent projects. Problems with schedule implementation and several mitigation strategies for reducing schedule risk will be presented as well as an industry example of improving production in a shipyard job shop.

### 2.1.1 History of CPM

E.I. DuPont de Numours (DuPont) developed the original concept of Critical Path Method in 1956, when after acquiring his UNIVAC1 computer he decided to use its computational power to bolster the company's planning, estimating, and scheduling department (Weaver 2006). The method, developed by Walker and Kelly, was first used on plant shutdowns in 1957 to solve the time-cost dilemma. The problem focused on adding resources to certain tasks to speed up project delivery while minimizing additional costs. Figure 2.1.1 shows direct and indirect costs and the total costs. In this example, a nine-day duration achieves the lowest total cost.

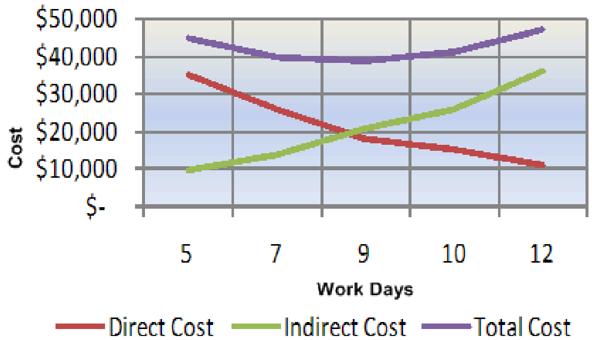



**Figure 2.1.1 Time-cost tradeoff curve (CPM Tutor 2010).**

The data needed for input and subsequent analysis caused engineers and schedulers to think in a new way. They had to relate subtasks and resources to cost and overall schedule, therefore it took several months to obtain this data. The computer's goal was to use linear programming to constrain sequencing and make solutions feasible using the i-j relationship between tasks. The ultimate goal was a time-cost tradeoff to find the shortest project duration at the least cost. DuPont eventually abandoned CPM because a new management staff didn't see or understand its value. Catalytic Construction of Philadelphia was the first large industry to use CPM in the early 1960s. Shortly thereafter, major industries like IBM and H.B. Zachry Company began to use CPM and precedence in computing. The Navy followed suit with John Fondahl's research on non-computer approaches to CPM. Future iterations of CPM were discovered with Program Evaluation and Review Technique (PERT) diagrams and Project software. Even with the transition to mini or mainframe computers in the 1980s, technology's involvement was still limited because computation time was very expensive. A lot of money was invested in training of the CP Method and manual calculating for schedulers. Scheduling was a highly sought after trade. Calculations were made manually and then, after several verifications of correctness, schedules were uploaded to computers. With the dawn of PCs, including the Microplanner and Primavera software in 1983, scheduling was a skill that anyone who could operate a computer could handle. The over reliance of computers to schedule projects caused a loss of scheduling know-how in many industries leading to problems with overall project success. New standards and scheduling certifications are now being introduced to marry advanced computing technology with sound judgment of trained professionals.

### 2.1.2 CPM in the Military and Methodology

The U.S. Navy adopted CPM in 1962 (otherwise called Critical Path Scheduling, Critical Path Analysis, Least Cost Estimating and Scheduling) for use in construction projects (Fondahl 1961). Computers did most complex CPM problems, but Fondahl was interested in a non-computer approach. Computer technology in 1962 had many limitations, including high cost, limited experience, extremely long computation time, and overall lack of access except for large firms. This method offered a "stepping stone" between manual calculations and computer methods. Fondahl's explanation of the method and specific benefits from its use are summarized in the following paragraphs.

Direct costs and time can be balanced to find the best schedule, but project tasks also have to be divided in several ways with respect to time, which makes this problem very difficult to solve. Project time, in order to reach minimum cost, needs to be compressed. Speeding up a project task can then have the negative effect of increasing direct costs as strategies like overtime, overmanning, advanced equipment, and other expensive methods are utilized. The problem is further complicated by tasks that have interdependencies and must follow a specific work sequence. This creates a web of overlapping and interrelated tasks. To determine the task that needs to be shortened to achieve the lowest cost is not always straightforward either. One could argue that it is better to shorten a task at great expense than to try and shorten a task cheaply that requires several other dependent tasks to be shortened. CPM is the systematic method for making such decisions using a mathematical algorithm. CPM provides five critical project data points which are: 1) the task that sets the total project duration (the critical path), 2) the quantitative “float” or “operation scheduling leeway” other tasks possess, 3) the most economical schedule for a given completion date while considering cost and time, 4) the completion date that coincides with the lowest cost, and 5) an assessment of how rework or growth work will impact the overall schedule or individual tasks within a schedule. There are three phases to the critical path method: Phase 1) Develop a network structure to identify tasks and their interdependencies on each other to form a sequence, Phase 2) is assigning the time estimate for each task, and Phase 3) is using computing power to find the time-cost relationships, review schedule variations, and pinpoint the solution. Phase 2’s time estimate may differ based on if Phase 3 is implemented. If Phase 3 is omitted, then time estimates (usually estimated in work days) will be found using standard estimating procedures. However, if Phase 3 is implemented, the time estimate should be input as the schedule that results in the lowest direct cost for the project (Fondahl 1961).

When beginning this method, one must determine whether the CPM will be used for resource oriented or time oriented scheduling. Resource oriented scheduling focuses on how to best use the resources so that they are used most effectively to save time and money. Time oriented scheduling focuses on determining the shortest project duration (Hendrickson 1989). A hybrid of the two scheduling techniques is also possible and focuses on resource leveling or constraining in the presence of sequencing tasks. Heuser and Wynne (1963) used CPM in load leveling of job shops to reduce lost work time and overtime. The focus was to level the job shops that are on the critical path and whose resources are fixed (i.e. they cannot be easily performed by other shops). This reduces the manual work that would be required to level every job shop within the schedule.

CPM has a language of its own and must be defined to understand the steps and deliverables. For Phase I, a Work Breakdown Structure (WBS) must be developed to define the sequential relationships amongst tasks. This can be a simple grouping of tasks in order of when they begin. However, more advanced visual diagrams are needed to map out the network of relationships. There are three main diagrams used in traditional CPM: The Activity-On-Arrow, the Activity-On-Node, and the Gannt Chart (bar chart) diagrams. Activity-On-Arrow diagrams uses arrow to show sequencing of tasks, where the head of an arrow represents a subsequent task and the tail represents a preceding task. The tail and head each have a number assigned to represent its sequence (where head>tail) (Figure 2.1.2). Activity-On-Node also uses arrows, but the activity is on the node itself and the arrows represent how the nodes are related (Hendrickson 1989) (Figure 2.1.3).

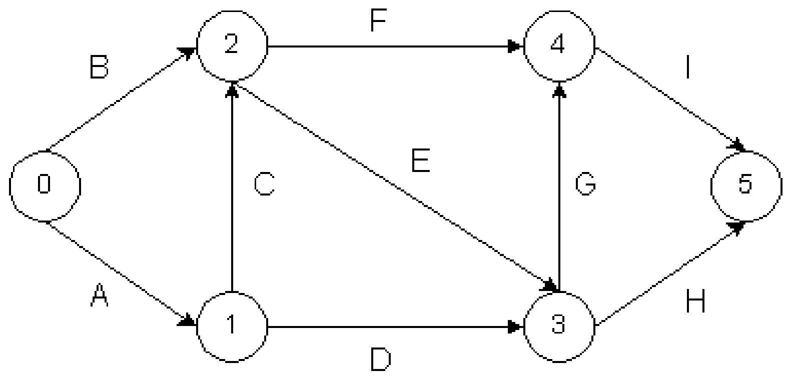



**Figure 2.1.2 Activity-On-Arrow Diagram (Hendrickson and Au 1989).**

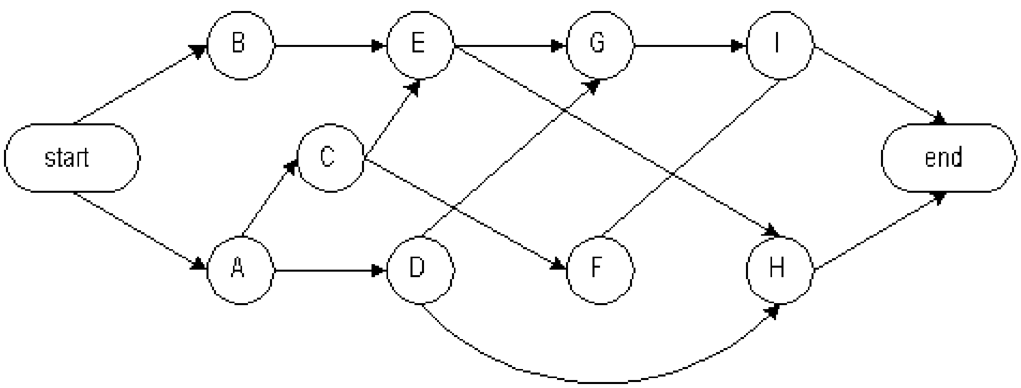
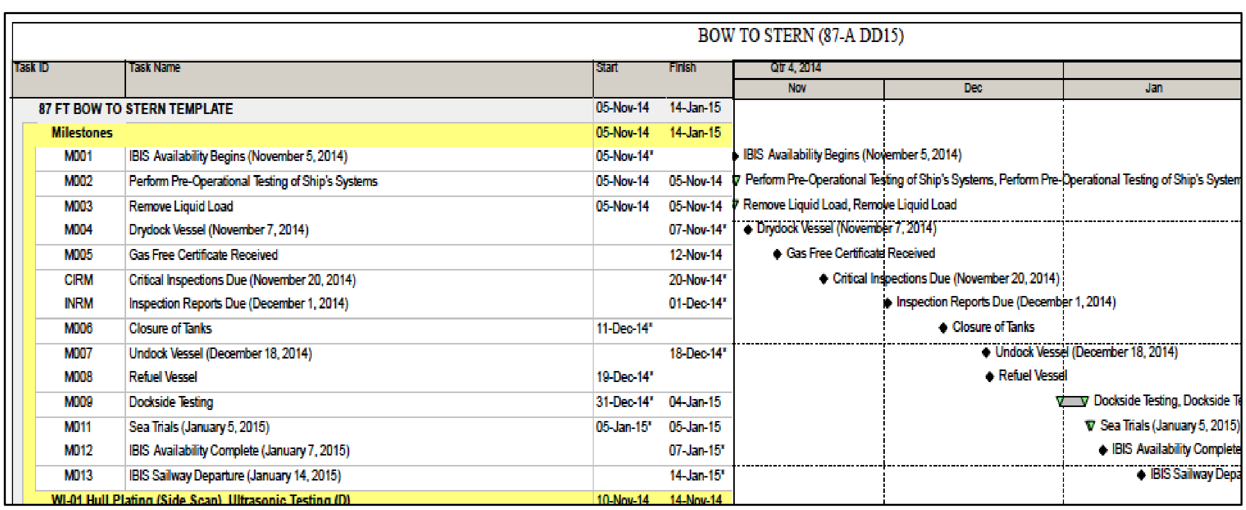



**Figure 2.1.3 Activity-On-Node Diagram (Hendrickson and Au 1989).**




| Task ID | Task Name | Start | Finish |
|---|---|---|---|
| | 87 FT BOW TO STERN TEMPLATE | 05-Nov-14 | 14-Jan-15 |
| | Milestones | 05-Nov-14 | 14-Jan-15 |
| M001 | IBIS Availability Begins (November 5, 2014) | 05-Nov-14* | |
| M002 | Perform Pre-Operational Testing of Ship's Systems | 05-Nov-14 | 05-Nov-14 |
| M003 | Remove Liquid Load | 05-Nov-14 | 05-Nov-14 |
| M004 | Drydock Vessel (November 7, 2014) | | 07-Nov-14* |
| M005 | Gas Free Certificate Received | | 12-Nov-14 |
| CIRM | Critical Inspections Due (November 20, 2014) | | 20-Nov-14* |
| INRM | Inspection Reports Due (December 1, 2014) | | 01-Dec-14* |
| M006 | Closure of Tanks | 11-Dec-14* | |
| M007 | Undock Vessel (December 18, 2014) | | 18-Dec-14* |
| M008 | Refuel Vessel | 19-Dec-14* | |
| M009 | Dockside Testing | 31-Dec-14* | 04-Jan-15 |
| M011 | Sea Trials (January 5, 2015) | 05-Jan-15* | 05-Jan-15 |
| M012 | IBIS Availability Complete (January 7, 2015) | | 07-Jan-15* |
| M013 | IBIS Sailway Departure (January 14, 2015) | | 14-Jan-15* |
| | WI-01 Hull Plating (Side Scan), Ultrasonic Testing (D) | 10-Nov-14 | 14-Nov-14 |

**Figure 2.1.4 Gantt Chart example from 87' Bow to Stern Program (CGC IBIS).**

Gantt Charts (named after Henry Gantt) visually shows the specific tasks that make up a project against time. A bar that spans some duration of time represents each task/activity (Figure 2.1.4). Gantt Charts are the primary diagram used in project planning. Activity diagrams have been phased out by precedence flow charts, representing qualitative as opposed to quantitative relationships. “Float” as mentioned above, can be broken up into free float (the amount of time a task can be delayed before it delays subsequent tasks) and total float (the amount of time a task can be delayed before it delays the project completion date) (Hendrickson and Au 1989). The “crash” time refers to the shortest time that every task can be completed (usually by adding resources), and this also represents the highest total cost called the all-crash cost (Fondahl 1961). The normal start refers to the duration of the project that results in the least cost, whereas the all-crash start refers to the smallest project duration with a higher cost. Constraints, in particular resource constraints are limitations to labor, equipment, and time within a given project time frame. Fast tracking is performing activities in parallel to reach a project deadline.

### 2.1.3 Advanced CPM Problems

Extensions in the CPM are necessary when intra-project scheduling, or scheduling of concurrent projects occurs. “The fundamental problem involved here is to find some way to define the many independent and combinatorial restraints involved into account: priorities, leveling manpower by crafts, shop capacity, material and equipment deliveries, etc.” (Weaver 2006). Risk management, particularly in the early phases of CPM, is crucial for obtaining reliable schedules. If the estimated task times are not realistic, then the proposed schedule is not going to lead to project success. Liberatore (2008) uses fuzzy logic to make best estimates for task durations in the absence of historical data. Fuzzy logic uses a forward and backward algorithm in a project network to "measure imprecision or vagueness in estimation" (Liberatore 2008). Typically CPM uses the likely task duration, PERT tends to underestimate task duration, and Monte Carlo Simulation can provide a task duration when the data is unreliable. Removing this uncertainty in estimates is an ideal first step in the CP methodology.

Easa (1989) uses CPM and integer-linear optimization models to minimize the variation in resources used. The model is applicable in small to medium construction projects with a single resource and continuous activities. The CPM solutions are interfaced to the model, which holds the objective function and constraints. The model can be extended to include multiple resources and provide a trade-off of cost scheduling. Lim et al (2014) also tackles the problem of extended CPM problems, but with a simulation system. Activities or projects that would normally be conducted in series are now completed in parallel in order to expedite completion times. Due to the limitations of scheduling software, Primavera schedules are exported to the Concurrent Construction Scheduling Simulation System (C2S2). This system is able to calculate rework probabilities as well as the variability in project completion time and cost by adjusting the overlap between activities. Greze et al (2014) work on resource-constrained project scheduling problems with overlapping modes (RCPSP-OM) using the basic premise of CPM while adding another project layer in parallel. This overlapping of work (or rework) implements a heuristic that moves the added work to downstream activities while resources are consumed at a constant rate throughout the schedule. The heuristic also assumes that the duration of rework is known in advance. The heuristic is used to either minimize project duration (by reducing cost of rework) or maximize project profits (by trading off between accelerating time and increasing project cost).

### 2.1.4 Schedule Implementation and Feedback Loops

When the proposed schedule is implemented in a project, any number of changes due to scope growth, rework, or resource adjustments can negatively impact the overall project success in terms of meeting a deadline and budget. As problems arise in a project, project managers must close the performance gap by working more or letting the deadline slip. Modifications to project plans and resources sets off a feedback loop. The different types of feedback loops are Experience Dilution, Too Big to Manage, Burnout, and Haste Makes Waste loops (Lyneis and Ford 2007). A closed feedback loop can be reinforcing (negative behavior) or balancing (goal-seeking behavior). Reinforcing loops can cause a project to reach its tipping point and spin out of control. "A tipping point is a condition, that when crossed, causes system behaviors to radically change performance" (Taylor and Ford 2008). Projects become overwhelmed and the workflow cycle becomes unbalanced.

Changes in a feedback loop can cause secondary and tertiary effects, called ripple and knock-on effects. Ripple effects and knock-on effects are usually negative consequences and impact productivity and work quality negatively by increasing the error fraction and rework. The different type of ripple and knock-on effects include creating out of sequence work (reduced productivity and increased errors), errors build on errors (reduce quality of downstream work), errors create more work (rework is more expensive time-wise than original work), and hopelessness (low morale causes increased errors and lowers productivity) (Lyneis and Ford 2007). Other factors that can compound the ripple and knock-on effects include scope changes, change orders, poor performance (leading to mistrust and requirements for additional progress reports), schedule pressure, and potential litigation. Schedule pressure causes work to be done at a faster pace, increasing risk for poor quality and the need for more rework, increasing the secondary effects of rework. Management is compelled to act when schedule pressure arises and will try to influence productivity by changing management techniques or adopting a wait and see strategy. Both techniques have consequences. Increasing staff and focus on design too late in the game can actually increase rework and decrease productivity. With labor costs representing about 30% of a total project cost, and 12% of costs being attributed to rework, getting a right balance is key. (Loushine et al 2006).

When managing the complexities of the feedback loop and follow-on effects, it is good to understand which has the most serious implications with respect to project resiliency. How to respond to the consequences is also paramount to getting a project back under control. Projects are least resilient to rework, followed by ripple effects and sensitivity to schedule pressure. Projects are most resilient to the project deadline. The solution to taming the rework cycle is to not overreact when a project’s performance starts to decline. Instead, overtime should be moderated, workers should be monitored for fatigue, less people should be hired, if hiring occurs only skilled workers should come onto the job, and staffing should be increased early in the project and with caution (Cooper 1994).

### 2.1.5 Schedule Risk Mitigation Strategies

As noted above, mitigation strategies have advantages for improving project performance if used properly, but also can bring about more reinforcing disadvantages if not monitored. Mitigation strategies can include overtime, overmanning, creating a multiskilled workforce, and implementing new tools or procedures. Backlog, or the work that is immediately available to be completed, should not be too low (two weeks per person) or too high (over four weeks) (Levitt 2009). Too low of a backlog results in slowing down work pace and can indicate overmanning, while too high of a backlog indicates overtime is needed. Having some overtime built into a project (approximately 3-9%, with a 6% target) indicates that the crew size is appropriate (Levitt 2009). On average construction workers are unproductive 40-60% of their day and 11% of project time is spent on rework (Loushine et al 2006). An average 8-hour shift might actually only produce 6-6.5 hours of work due to meals, breaks, and meetings (Levitt 2009). Overtime in construction is defined as working over 40 hours per week, or over eight hours per day according to Brunies and Emir (2001). The literature on impacts of prolonged overtime on project performance are mixed in their views, mostly because of the lack of industry-specific or even project-specific studies available. Many authors even question the soundness of several studies that have been conducted on overtime's effects on productivity. The problems with many of these studies are that the data, namely efficiency loss charts, is unoriginal or outdated, and much of the data has been reprinted or reused inappropriately (Brunies and Emir 2001). Singh (2003) details how overtime techniques are used when project schedules become compromised using an Army Corps of Engineer efficiency loss study from the 1960s. In this case, overtime, when used regularly or in excess had a negative consequence on work efficiency. Furthermore, Singh outlines how to use overtime efficiency curves to calculate the number of workers needed for overtime by including the efficiency losses due to overtime. Calculating efficiency loss is an iterative process and oftentimes is not conducted at job sites. By obtaining these industry-specific details, organizations can more appropriately assign workers to overtime. Sonmez (2007) conducted a similar efficiency study on a construction project involving concrete pouring, forming, and finishing, noting anywhere between 8% and 22% productivity loss due to factors like fatigue, increased absenteeism, and low morale. However, it was also noted that moderate levels of occasional overtime do not significantly impact productivity. Overtime, if not used properly, can impact the feedback loop negatively. Working extended overtime may seem like the answer to getting back on schedule, but the secondary effects of overtime on the feedback loop can add up to reduce and even negate the extra output hours gained.

Shift work, is defined by the National Institute of Occupational Safety and Health as "working outside normal daylight hours" (Hughes and Stone 2004). Shift work can be evening shifts, night shifts, rotating shifts, or split shifts. The shifts that have the biggest negative influences on work performance due to fatigue, sleep loss, and sleepiness are the night shift and rotating shifts (Hughes and Stone 2004). Jamal and Jamal (1982) studied the work performance of manufacturing laborers on fixed or rotating shifts. Those on fixed shifts (highly routine oriented) had better job performance and motivation than their counterparts on a rotating shift (low routine oriented). Lagodimos and Mihiotis (2006) weigh the costs associated with no overtime, full overtime, or adding additional shifts by using linear optimization to minimize overall labor costs. The optimal value for each scenario varies for the workload of that day. For example, it is better to use one shift (versus two shifts) if the remaining work (past one shift) is significantly less than a full shift's work. In other words, it is less costly to utilize overtime for one shift than to add an additional shift where workers will be underutilized. This is assuming that the total workforce needed while utilizing overtime is reduced. Furthermore, the use of overtime plus an additional shift (if needed) can also reduce overall labor costs due to the improved manpower utilization.

When overtime fails, managers start hiring new people or use subcontractors. Hiring additional workers can introduce lower skills and experience levels, requiring more time for managers to train and increasing the chance for rework. Having too large of a workforce can increase errors and reduce productivity due to poor communication and congested workspace (Lyneis and Ford 2007, Cooper 1994, Singh 2003). With hiring low skilled workers, another effect comes into play: secondary effects of low-quality work. Low quality work increases rework, even more than the original work's rework contribution. For this reason, additional supervision is required when overmanning a project.

Wang et al (2009) detail one of the strategies for improving workforce capabilities, namely the multiskilled workforce. The study used correlation and cluster analysis to determine if multiskilling increases productivity, quality, and continuity of work. The results of the cluster analysis showed that craft skills (like job shops) could be grouped into civil, mechanical, electrical, and general support work. The motivation behind becoming multiskilled is to increase functionality, not to prolong employment. Burleson et al (1998) defines several multiskilling strategies and determines their impact on required workforce, turnover/absenteeism, earning potential, productivity, job satisfaction, and innovation/technology implementation within the construction industry. Four types of multiskilling strategies were defined and evaluated in this study: Dual Skill, Four Skills, Four Skills-Helpers, and a Theoretical Maximum Labor Strategy. Dual Skill groups two different skills together based on the number of workers needed and the timing of the need, ignoring their craft identifiers. Four Skills groups the crafts into four broad categories: civil/structural, general support, mechanical, and electrical workers. Four Skills-Helpers strategy uses the same categories, but uses unskilled laborers as helpers for the skilled laborers. This strategy allows unskilled laborers to experience a wide range of skillsets at a time in their career where they can be broadened prior to attending trade schools. The results indicated that the Four Skills-Helpers strategy was the most successful, producing total labor cost savings of between 5% and 19%. The required workforce was reduced by 35% and employment duration increased 47%. Some of the barriers for implementing the multiskilling strategies include the challenge of changing the culture of the industry, including hiring, compensation, staffing, and project management practices. The availability of training and the difference in implementation between maintenance and new construction may be different.

Mayer et al (2008) experiment with implementing Jobshop-Lean through a change from a process layout to a cellular layout in the Navy's Southeast Regional Maintenance Center (SERMC). The SERMC is a ship repair facility that has individual shops based on trade skills. This type of layout suits organized trades, but also incurs many of the eight wastes identified through the Toyota Production System (or Lean). Transportation and operator motion wastes are very common with job shops, as they are not collocated with the project. Jobshop Lean is a version of Lean that is useful for high-variety low-volume facilities like SERMC. Cellular layouts are ideal for grouping dissimilar machines with varying capabilities in one location. The conversion of process layout to cellular layout requires a large capital investment and is not a viable option for many established shipyards. Focused factories and virtual cells are alternatives to the typical cellular layout. Focused factories are made in order to focus a company's manufacturing processes on a set of chosen products based on the company's strategy, technology, or economics. Virtual cells remove the need to collocate machinery into one area and instead dedicate tools, parts, and people into a cell. Capital investment requirements are limited, however the identified wastes are not removed. Communication and information flows precede material flows, and therefore are a major cause of delays. Electronic communications are essential for allowing just in time (JIT) deliveries in a virtual cell. "Simulation results showed that implementing either physical cells or virtual cells based on the different families of repair jobs could improve job turnaround times" up to 37-82% (Mayer et al 2008). The many challenges of implementing virtual cells include cross training, redistributing machinery, and increased IT-supported communication devices. The advantages of implementation, however, include increasing throughput and decreasing lead-time and cycle time.

### 2.1.6 Effects of Learning Curves

Due to the assembly line nature of the 87' Bow to Stern Program, it should be expected that a learning curve will develop with time as the laborers become more familiar with the platform and adapt sequencing to achieve greater efficiencies. Learning curve gains are achieved by progressing along a curve or by skipping to a new, more favorable curve. Movement along a curve is linked to Continuous Improvement and Six Sigma, whereas jumping curves is linked to Theory of Constraints.

Different levels of learning can occur at the research, development, design, materials, components, subsystems, product (system), use, maintenance, and end-of-life utilization stages (Linton and Walsh 2013). Ash and Smith-Daniels (1999) look at the impacts of learning, forgetting, and relearning (LFR) on project completion time when preemption (or an interruption of a task) occurs. A penalty toward learning curve progress is applied because the continuous learning process is interrupted. The goal was to see if LFR in multi-project settings without this penalty leads to poor decisions, increased project time, and poor resource utilization. The results show how total project time increases due to the forgetting and relearning periods. There is also a high correlation between learning and forgetting rates. Some studies have shown a common forgetting rate of 26% for one month of time. Direct learning (or learning by doing) accounts for 38-46% of production cycle time reduction and indirect learning (or transfer of knowledge) accounts for 14-18%. Furthermore, knowledge acquisition is dependent on the number of units produced whereas knowledge depreciation is dependent on accumulated knowledge and the time elapsed between when knowledge is acquired and when it is utilized (Kim and Seo 2009). Boucher (1987) provides an analysis of the relationship between learning, assembly line design, and labor productivity. Learning can be accomplished through repetitive task learning or through creating multiples of the same product through production progress function. The results show that in deciding between an assembly line or single worker completing a product, "relative productivity increases with increasing division of labor" (Boucher 1987). Also, for manual production tasks, twice the number of individual workers would be needed to get the output of an assembly line with four stations. Learning rate, which was assumed to be constant, changes with fluctuations in cycle time or task length (decreases with increasing cycle time), job satisfaction or motivation (increases with increasing motivation), and lot size (higher learning rates are required for decreasing lot sizes for individual workers compared to assembly lines).

### 2.1.7 Similarities and Differences to Line Balancing

In manufacturing, the use of assembly lines allow for greater efficiencies in time and use of resources. The CG Yard 87' Bow to Stern Program could be looked at as an offset parallel assembly line, but it differs greatly from standard assembly lines and therefore typical line balancing solutions may not be appropriate for this example. Scholl et al (2008) uses knowledge of the simple assembly line balancing problem (SALBP) to look at the solvability of the sequence-dependent assembly line balancing problem (SDALBP). SALBPs are good for high volume of one homogenous product with set resources and cycle times for a serial line layout of multiple stations. The SDALBP is more complicated as there is a precedent relation for tasks. Sometimes the precedent is a technological requirement (no way of working around it) or because it is assumed to be a more efficient ordering of tasks (mathematically solved). The interaction between tasks can be unidirectional (i only affects j) or bidirectional (i affects j and j affects i). Precedence graphs are used to show these relationships in an assembly flow. Optimizing task time, or the sum of all task times plus the minimum interacting task time, is the goal of the ALBP. The SDALBP, which if feasible is NP-hard (nondeterministic polynomial time), can be generalized to a SALBP by setting all interactions to zero. An SDALBP can also be simplified to a SALBP through relaxation (setting a lower bound) and transformation (setting an upper bound) and each solvable SALBP's feasible or optimal solution is also a feasible (but not necessarily optimal) solution for SDALBP. The solutions to the SALBP are inputs to the modeling software (SALOME) to solve the SDALBP problem. Optimal solutions are found when interaction pairs are high, but standard models do poorly with more than 30 tasks. Overall however, about half of the SALBP solutions are SDALBP-infeasible. This infeasibility increases with increased task time increments and underestimates total number of stations. Overestimations can lead to wasted resources, therefore it is better to model precedence relationships (Scholl et al 2008).

Gokcen et al (2006) detail proposed procedures for balancing parallel assembly lines with the goals of minimizing worker stations and idle time. Assembly lines must have a total task time less than or equal to the total cycle time as well as follow the appropriate sequencing. There are two types of assembly lines, the traditional and U-type, which can deal with single and multi/mixed products. Multiple assembly lines can be beneficial during high demand periods, assuming the resources are available, and prevent production failures in the event of an assembly line crash. The authors propose a procedure to balance parallel lines by assuming one product per assembly line, with known precedence diagrams and known task times, in which the workers are multi-skilled and interchangeable, and tasks can be worked on each side of the line. The passive procedure is the case where two assembly lines are producing the same products, the active procedure is the case where similar or different products are being made in multiple parallel lines, and finally when task time varies between lines. All three examples are solved theoretically and numerically. Of the 95 problems in this study (1-30 tasks) with known optimal solutions (found by other methods), 44 were solved using the mathematical model. The established procedure proved efficient to use when more than one assembly line requires balancing.

Brown et al (2002) detail a cost minimizing optimization model, called PROFITS, for plant-line scheduling of multiple product package items over a multi-week planning horizon for the Hidden Valley Company. The goal of the optimization model was to aid schedulers in developing a better schedule while reducing time and cost. Optimization models often times do not produce ideal schedules because they must make broad assumptions and rely on heuristics to fine tune the final product. The PROFITS model takes into account resource limitation as well as sequential and parallel work dependencies. The model is capable of producing schedules quickly, but requires schedulers to fine tune details and implement rules of thumb to create a finished final production schedule.

### 2.1.8 Industry Example

NASSCO is a shipbuilding facility located in San Diego California. The shipyard was searching for ways to improve the efficiency of the production flow and sequencing of products given the difficult circumstances of producing ships (low material utilization and high inventory/work in progress). NASSCO wanted to improve the pipe shop’s manufacturing line by optimizing flow while taking into account individual process times, work station capacities, engineering design, schedule changes, and level loading of shops. The shipyard looked to their counterparts in Japan at Kawasaki Heavy Industries' shipyard who had implemented pipe spool fabrication practices with dynamic nesting of pipe materials. The process to implement a similar program at NASSCO included conducting a feasibility study, creating a detailed application specification for the system (which included data flow requirements between scheduling and parts databases/spreadsheets, business process changes, and operator interfaces/report), and developing evaluation factors for initial implementation and future operations. The goals of the improved pipe component routing and nesting were to be more flexible with work plan changes and schedule changes, and to keep level shop loading. NAASCO interfaced their scheduling system, product design software, and a newly created Pipe Shop Management System (PSMS). The material resource requirements (current and future) were input either manually by schedulers or automatically by an algorithm into an excel file that was automatically bound to the management system. The software was capable of taking planning data for two weeks out and, using averaging and work-content-based families (for different pipe spools), schedule the number and type of pipe spools to be created in a given week. Weekly plans were then level loaded using the PSMS for more predictable work schedules and part production. After implementation, NASSCO's pipe shop observed several performance benefits including reduced planning labor, reduced work in progress (WIP) and scrap remnants, and increased production efficiency (General Dynamics-NASSCO 2008).

## 2.2 Hypotheses

The CG Yard will face potential delays due to excessive loading of resources, particularly for the paint shop. This will be shown through an analysis of the WBS sequencing and task duration estimates plotted over time for multiple, overlapping availabilities using spreadsheet modeling. Due to the inflexibility of the schedule and the potential for schedule risk, viable mitigation strategies will need to be established and prioritized based on their usefulness and feasibility to the CG Yard. By level-loading a single job shop, resource costs can be reduced by creating more predictable job shop schedules and reducing overtime needed. The CG Yard's standard management practices and their available scheduling software can be improved by better methods and software. The CG Yard can reduce the need for schedule risk mitigations strategies and guesswork by implementing an Integrated Master Plan and risk management techniques into their scheduling and estimating departments. Finally, due to the CG Yard's high fluctuation of management personnel due to the active duty job rotation, lessons learned from current and previous projects or programs will be difficult to implement, but will be necessary for future project success.

# CHAPTER 3

# DATA ANALYSIS

The CG Yard's Industrial Small Boat and Patrol Boat Product Line Asset Program Manager, Lieutenant Commander Miles Randall provided the data needed for analysis. Raw data was transmitted via email and taken from the CG Yard's scheduling and estimating databases (M.R. Randall, personal communication-email September 15, 2014). The raw data includes the 37 work item specification, the list of CG Yard Job Shops with the available labor resources for the program, the original Gantt chart, the sequencing plan in a Work Breakdown Structure (WBS), and the Section B that has all estimated man-hours per job shop, material costs, as well as estimated costs (U.S. Coast Guard Industrial Yard, 2014-2015).

Prior to beginning the Bow to Stern Program, the lead estimator Raymond Dix laid out the proposed schedule and pointed out what is typical of an 87’ project and where there may be concern for the Bow to Stern Program. The original schedule was for a 9-week availability, with 9,050 man-hours (8,008 definite hours) in 40 work items. He predicted needing the 25.1 (22.2) laborers per day to complete this project (R.L. Dix, personal communication-email September 13, 2014). Normally, an 87’ availability would not exceed 20 people per day due to crowding on the vessel, so he proposed an 11.3-week availability. If only definite items were to be completed, the standard 10-week availability would suffice given limited growth. Any activation of an option item would extend the schedule 1-2 weeks. As for the paint shop, Mr. Dix predicted needing 7 painters per day in 9-weeks or 6.25 painters per day in 10-weeks (for the given 2,496 man-hours estimated). A typical 9-week availability would only require 1,080 man-hours (1,200 for 10-weeks). To reduce overcrowding, three painters per day maximum would be ideal. The use of two shifts would allow the three people per shift and meet the 9-week time frame, but it would be extremely tight.  The CGC IBIS’ availability was scheduled for 10 weeks with the hopes of reducing the necessary timeframe to 9 weeks by the fifth availability, CGC POMPANO. A 60-day (8.5-week) availability is the ultimate goal of the program.

The first five Coast Guard cutters (CGC) and their schedules are listed below in Table 3.1. After project completion, each cutter will have all of their data accessible through the project management online tool called Contract Workbook Database. From here, a myriad of documents can be obtained to see weekly project status, final cost reports, schedule changes, etc.

| Cutter Name | Scheduled Maintenance Availability |
| --- | --- |
| CGC IBIS | 04 November 2014 – 14 January 2015 |
| CGC STINGRAY | 30 November 2014 – 11 February 2015 |
| CGC HAMMERHEAD | 05 January 2015 – 24 March 2015 |
| CGC BLUEFIN | 01 February 2015 – 08 April 2015 |
| CGC POMPANO | 09 March 2015 – 17 May 2015 |

**Table 3.1 Program Schedule for First Five Availabilities.**

The Revision-0 specification (Rev0 final specification) is the legally binding contract between the Coast Guard and the CG Yard. It details all the work to be completed and includes references to more specific technical specifications and drawings. Work items are defined as either being definite (work will be completed no matter the condition of the cutter) or optional (work will be completed dependent upon the condition of the cutter). The specification says "what" is to be completed, not "how". The sequencing of work, given knowledge of how a ship is assembled can be derived from the specification. The list of work items from the Rev0 specification for the 87 Bow to Stern Program is located in Figure 3.1 (Nakoa 2014).

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**Figure 3.1 Excerpt from Rev0 Specification Listing Availability Work Items.**

The CG Yard industrial workforce is composed of 416 wage-grade unionized laborers that work for varying job shops. The job shop's labor capacity is divided amongst the ongoing projects based on priority and schedule. Table 3.2 lists the job shops by title and their area of expertise (CG Yard Website 2014). For the 87' Bow to Stern Program, the CG Yard estimated needing 25.1 people per day for both definite and optional work items or 22.2 people per day for definite items only. The other labor/schedule restriction for the project is that every job shop, with the exception of the paint shop (X-42), will be working single shifts (8 hours) on weekdays with overtime contingent upon growth work or rework. The paint shop will work double shifts and weekends/holidays. Six workers will be available for the overtime work (3 painters per shift). The CG Yard follows the federal holiday schedule and typically no work is conducted on those days.

| Shop Number | Description |
|---|---|
| X-11 | Shipfitting/Structural |
| X-12 | Sheetmetal |
| X-13 | Welding/Structural |
| X-14 | Woodworking/Firewatch |
| X-21 | Pipe Shop |
| X-22 | Inside Machine Shop (Lathes, etc.) |
| X-23 | Outside Machine Shop/Marine Machine (Propulsion, Shafting, etc.) |
| X-24 | Engine Shop |
| X-31 | Electrical Shop |
| X-32 | Electronics Shop |
| X-33 | Ordnance Shop |
| X-41 | Paint/Blast |
| X-42 | Paint Shop |
| X-43 | Rigging (Cranes, Forklifts, etc.) |
| X-44 | Drydock (Cradle Prep, Docking, etc.) |
| X-60s | Support/Engineering |

**Table 3.2 CG Yard Job Shops.**

The original Gantt chart was developed with the standard management practices in mind. Approximately three months prior to the program start, the management team decided to adopt a new practice for the first 87' cutter IBIS. The plan was to scrap the scheduler's developed Gantt chart and allow the job shop foremen to sequence work as they progressed through the work items. This would allow the maintenance experts the flexibility to craft the best methods of sequencing instead of following a scheduler's detailed plan. As is the case with the CG Yard, the foremen are busy year-round and do not have the time to work with the schedulers to fine-tune each cutter's schedule. By using the first cutter as a prototype schedule, and capturing the data for work-item sequencing and actual man-hours expended, the schedulers could then fine-tune a new Gantt chart for the following cutters.

The Work Breakdown Structure provided by the CG Yard program manager and the shop foremen, defines a sequencing plan for CGC IBIS. It is a general plan that highlights the major work item requirements in a calendar timeline. The broadness of the schedule allows the foremen to adapt to unforeseen complications during the first run of the contract. This characteristic of the schedule also complicated the procedure of level loading resources for this study, as several assumptions needed to be made about detail work sequencing even after referencing the specification. The IBIS WBS schedule is shown in Table 3.3.

| **Monday 11/3** | **Tuesday 11/4** | **Wednesday 11/5** | **Thurs 11/6 -COB Wed 11/12** | **Thurs 11/13** | **Friday 11/14-COB Sat 11/22** | **Sunday 11/23** | **Sunday 11/23-Tues 12/02** |
|---|---|---|---|---|---|---|---|
| | Ride in & Pre-op test | Measures propulsion shaft shims and pre-docking propulsion shaft hub alignment (23) **Work Item 36** | Drydock Cutter | Seal Enclosure Install Temp Services | Blast 100% & Prime UWB | Commence Side Scan | Gray Water & Sewage Pipe Flush (To be coordinated w/side scan- s/s work hours start at 1500) |
| | | Remove liquid loads (CTR) | Clean Bilges/Tanks (CTR) Marine Chemist/ Gas Free Cert. | Mobilize Blast Equipment | Blue Fit Props | | Remove Bilge and Lazarette interferences |
| | | Pull TLIs | Remove mast interferences, coil up cables, protect coiled up cables | Bearings/RedGear Optical Alignment | Prep Sea Valves for Install | | Install Shaft bearings |
| | | Open Fuel, Sewage, Dirty Oil, Waste Oil, and Grey Water Tanks | Remove Sea Valves & Speed Log Valve | | Complete Mast Mods | | |
| | | | Remove underwater appendages Rudders, Shafts, Props | | | | |
| | | | Remove Stern Door & Notch Pads | | | | |
| | | | Commence Cover-Ups | | | | |
| | | | | | | | |
| | | | | | | | |
| **Mon 12/01-COB Wed 12/10** | **Thurs 12/11-COB Tues 12/16** | **Wed 12/17-COB Mon12/29** | **Tues 12/30** | **Wed 12/31-COB 1/02** | **Mon 1/05-COB Thurs 1/8** | **Fri 1/09-COB Tues 1/13** | **Wed 1/14** |
| Prep/paint Cutter | Install Interferences | Open Structure | Undock Vessel | Take Final Face Readings | Dock Trials | Crew Arrives | EOIW- Cutter Departs |
| Capastic Fairing | Load Sea Valves | Notify Crew of Reporting Date | Refuel Vessel | Elex Testing | | Outfit Onload | |
| | * Night Shift X-42* Paint ER Bilge & Lazarette | Install Mast | Fill P/W Tanks | Clean Vessel (CTR) | | Sea Trials | |
| | Install Hull Zincs | Install U/W Appendages | Load Small Boat | | | Final Walk-Thru | |
| | Lay Deck Pads | Install Sea Valves and Speed Log Valve | | | | | |
| | | Shaft Seal Piping Install | | | | | |
| | | Install Lagging | | | | | |

**Table 3.3 Work Breakdown Structure Timeline for CGC IBIS.**

The Section B is a document created by the Estimators that has all estimated man-hours per job shop, material costs, as well as estimated costs. This document was used to pull all of the man-hour data per task into the resource-loading timeline. It was not disclosed whether or not the estimators built in a cushion to these estimates. It is unknown whether or not these deterministic values represent the minimum, average, maximum, or any value in between of the labor required.

The estimators do not use historical data to their full advantage, which has caused under and overestimations. An estimate will be generated based upon the number of workers needed per task and their likely duration. This data is used over and over without ever being updated by the actual man-hours expended. The values being reused are more of a best approximation and do not account for the fact that task duration has a distribution. The deterministic values were used in the level-loading scenario, which may be a limitation to the analysis as the required man-hours for each cutter will be stochastic in reality. The deterministic values, however, will give a reasonable assessment of reality given that the foremen and laborers that oversee and complete these tasks on a daily basis submitted the man-hour estimates to the estimators. With the use of a distribution of task duration times, the CPM would be more robust and result in more accurate schedules. A sample work item estimate (called a CLIN estimate) is provided in Figures 3.2 and 3.3.

| Labor Rate | | $77.23 | $75.67 | $74.85 | $75.50 | $58.96 | $80.89 | $75.41 | $79.91 | $80.80 | $77.88 | $89.02 | $80.50 | $82.65 | $72.14 | $79.30 | $86.42 | $119.68 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| REV: 10/01/13 | | 11 | 12 | 13 | 21 | F/W (X14) | 22 | 23 | 24 | 25 | 31 | 32 | 33 | 41 | 42 | 43 | 44 | 61 |
| 1 | L | 0 | | | | | | | | | | | | | | | | 2 |
| | M | 175 | | | | | | | | | | | | | | | | 950 |
| | | MATERIAL FUNDS & CONTRACTOR SERVICES | | | | | | | | | | | | | | | | |
| 2 | L | 2 | | | | | | | | | 2 | | | | | 2 | | |
| | M | 0 | | | | | | | | | 0 | | | | | 0 | | |
| | | OPEN TANKS/BILGES | | | | | | | | | | | | | | | | |
| 3 | L | 2 | | | 3 | | | | | | 3 | | | | | | | |
| | M | 0 | | | 0 | | | | | | 0 | | | | | | | |
| | | INSP TANKS/BILGES | | | | | | | | | | | | | | | | |
| 4 | L | 6 | | | 2 | | | | | | 3 | | | | 2 | | | |
| | M | 0 | | | 0 | | | | | | 0 | | | | 0 | | | |
| | | FINAL INSP TANK/BILGES | | | | | | | | | | | | | | | | |
| 5 | L | 2 | | | | | | | | | 2 | | | | | | | |
| | M | 0 | | | | | | | | | 0 | | | | | | | |
| | | CLOSE TANK/BILGE | | | | | | | | | | | | | | | | |
| 6 | L | | | | | | | | | | | | | | | | | |
| | M | | | | | | | | | | | | | | | | | |
| TOTALS | L | 12 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 2 | 2 | 0 | 2 |
| | M | 175 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 950 |
| | | 11 | 12 | 13 | 21 | F/W (X14) | 22 | 23 | 24 | 25 | 31 | 32 | 33 | 41 | 42 | 43 | 44 | 61 |

**Figure 3.2 Example CLIN Work Item Estimate for Bow to Stern Program. Job shops listed across top columns with labor rate, subtasks with duration estimates in each row.**

| Labor Rate | | $77.23 | $75.67 | $74.85 | $75.50 | $58.96 | $80.89 |
|---|---|---|---|---|---|---|---|
| REV: 10/01/13 | | 11 | 12 | 13 | 21 | F/W (X14) | 22 |
| 1 | L | 0 | | | | | |
| | M | 175 | | | | | |
| | MATERIAL FUNDS & CONTRACTOR SERVICES | | | | | | |
| | | | | | | | |
| 2 | L | 2 | | | | | |
| | M | 0 | | | | | |
| | OPEN TANKS/BILGES | | | | | | |
| | | | | | | | |

**Figure 3.3 Zoomed-in example CLIN Work Item Estimate for Bow to Stern Program. Job shops listed across top columns with labor rate, subtasks with duration estimates in each row.**

# CHAPTER 4

# METHODOLOGY

## 4.1 Experimental Design

In order to determine if the estimated number of man-hours could be completed in the allotted time schedule and in such a way that the job shops would be working equally loaded workdays (one 8-hour shift), an Excel Workbook with several spreadsheet models was designed to enter man-hour, schedule, and sequencing data. Each job shop is listed in its own row, calendar dates are listed in each column (based on first availability November 1$^{st}$ – January 14$^{th}$), and man-hours are filled in the corresponding row/column. This was first done on a micro scale for each job shop and then filled in a final worksheet containing all data points. Spreadsheet modeling in Excel is an appropriate method for evaluating raw data when advanced software is not available due to economic and skilled-user restrictions. This type of modeling can be time consuming, however, explaining why the CG Yard planning team did not conduct it themselves.

The next section will detail the procedures needed in order to get the raw data into a meaningful schedule and showcase the important analysis and results of spreadsheet modeling.

## 4.2 Procedures & Assumptions

Given the scheduling and estimate data from the CG Yard, the applicable data had to be compiled into one spreadsheet to determine if the project could be level-loaded. In this process several assumptions were made in order to make progress. The sole variable used in the analysis is man-hours.

The workbook was organized to create a tab for each job shop. With the aid of the CLIN estimates, Rev0, and WBS, each work item was evaluated and the man-hour data was placed within a range of dates the work would most reasonably be completed in. The ranges of dates for specific work were taken from the work sequencing WBS where the CG Yard foremen and program manager had grouped work that would be done in parallel. Some dates were single days, such as for docking and undocking the ship, but others were broken into one or two week periods (Refer back to Table 3.3). The WBS does not schedule work over weekends or holidays, so it was assumed that no work would take place at that time with the exception of the paint shop (X-42) as determined by the CG Yard. The CLIN estimates have very specific tasks to be completed and many of these subtasks were not defined in the WBS. Therefore, the dates for these subtasks were not obvious. To account for this, the Rev0 specification and previous Naval Engineering knowledge was used to make a best guess on how the work was to be sequenced. Table 4.2.1 shows an example of a completed job shop’s initial breakdown of man-hours per time period.

| Work Item # | Description | Job Shop | Man-Hours | Date to Complete |
|---|---|---|---|---|
| wi 10 | preparation | x11 | 4. | 12/31-1/2 |
| wi 10 | alignment | x11 | 4.00 | 12/31-1/2 |
| wi 15 | preparation | x11 | 12.00 | 11/14-11/22 |
| wi 16 | protective meas. | x11 | 2.00 | 11/6-11/12 |
| wi 16 | remove (propeller) | x11 | 2.00 | 11/6-11/12 |
| wi 2 | ut shots | x11 | 8.00 | 1-Dec |
| wi 20 | visual inspection | x11 | 2.00 | 4-Nov |
| wi 20 | remove (stern launch door) | x11 | 10.00 | 11/6-11/12 |
| wi 20 | install (bracing) | x11 | 4.00 | 11/6-11/12 |
| wi 20 | install (stern launch door) | x11 | 10.00 | 18-Dec |
| wi 21 | open tanks | x11 | 2.00 | 5-Nov |
| wi 21 | inspect tanks | x11 | 4.00 | 12-Nov |
| wi 21 | final inspect | x11 | 8.00 | 12/11-12/16 |
| wi 21 | close tanks | x11 | 4.00 | 12/11-12/16 |
| wi 22 | open tanks | x11 | 2.00 | 5-Nov |
| wi 22 | inspect tanks | x11 | 4.00 | 12-Nov |
| wi 22 | final inspect | x11 | 8.00 | 12/11-12/16 |
| wi 22 | close tanks | x11 | 2.00 | 12/11-12/16 |
| wi 25 | preps/removals | x11 | 10.00 | 13-Nov |
| wi 25 | reinstalls | x11 | 10.00 | 12/11-12/16 |
| wi 26 | preparation | x11 | 14.00 | 13-Nov |
| wi 26 | reinstalls | x11 | 10.00 | 12/11-12/29 |
| wi 27 | preps/removals | x11 | 16.00 | 11/6-11/12 |
| wi 27 | reinstalls | x11 | 19.00 | 12/17-12/29 |
| wi 28 | preps/removals | x11 | 14.00 | 11/6-11/13 |
| wi 28 | reinstalls | x11 | 16.00 | 12/11-12/29 |
| wi 29 | renew zinc anodes | x11 | 34.00 | 12/11-12/16 |
| wi 30 | dry dock vsl | x11 | 18.00 | 6-Nov |
| wi 30 | undock vsl | x11 | 9.00 | 30-Dec |
| wi 33 | crop/renew | x11 | 45.00 | 11/23-12/2 |
| wi 34 | preps/removals | x11 | 10.00 | 13-Nov |
| wi 34 | reinstalls | x11 | 6.00 | 12/11-12/16 |
| wi 36 | protective meas. | x11 | 2.00 | 11/6-11/12 |
| wi 36 | interferences | x11 | 4.00 | 11/6-11/12 |
| wi 36 | major misalignment | x11 | 8.00 | 11/13-12/2 |
| wi 36 | remove (shafts) | x11 | 7.00 | 11/6-11/12 |
| wi 36 | inspections | x11 | 4.00 | 11/6-11/12 |

**Table 4.2.1 Initial Data Organization for Job Shop X-11.**

Another problem encountered with the CLIN estimates was that certain subtasks, like removing and installing interferences, were listed together with one man-hour estimate. To simplify, it was assumed that installations and removals take equal time and therefore any sub item listed as install and remove is split in half equally. For any overarching work items (temporary and support services), the total man-hours for the project were divided by total workdays (excluding weekends and holidays) and then added to that day's total resource requirement. For other tasks that require very few man-hours (for instance, 2 hours), but are scheduled to span a handful of days, the total time was placed in the first day of the range or the day in the range with the fewest man-hours. For tasks exceeding 8 man-hours in one day, the WBS and Rev0 were referenced to see if the dates were fixed based on sequence or if they could be broadened. Some tasks exceeding 8 hours per day were extended into the next day or following week and for other tasks that would become out of sequence if expanded, it was assumed the extra man-hours would be covered by an increase of resources in that job-shop. After entering man-hours into dates for all tasks and job shops, the Rev0 specification was reviewed again to make sure that there weren't any obvious tasks missing from the CLIN estimate spreadsheet. Only a handful of missing items were found and their man-hours were added to the spreadsheet. After this initial organization, a chart was made of the man-hours onto a calendar. To do this, all of the man-hours for each date or range of dates were summed up and then divided by the number of workdays in that range. To ensure the numbers were true to the CLIN estimates, work hours in the man-hour column as well as in the calendar portion were summed to verify they were the same.  In order to see the total impact of parallel work from subsequent availabilities, the data from the first availability was copied into the schedule for the second and third availabilities. From this point, more adjustments had to be made to the man-hours because when transferred, man-hour data filled into weekends or holidays. Once all three availabilities were overlapped on one schedule, their columns were summed to calculate the total number of man-hours required to stay on schedule. Man-hours per shop over time were then plotted (04 November 2014 to 14 January 2015 when three cutters were being overhauled). Figures 4.2.1 and 4.2.2 shows shop X-11's schedule for the first three availabilities, CGC IBIS, CGC STINGRAY, and CGC HAMMERHEAD.

| | Availability Start Date | | | | | | Weekends/Holidays | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| X-11 | 4-Nov | 5-Nov | 6-Nov | 7-Nov | 8-Nov | 9-Nov | 10-Nov | 11-Nov | 12-Nov | 13-Nov | 14-Nov | 15-Nov | 16-Nov | 17-Nov | 18-Nov |
| IBIS | 2 | 52 | 34.6 | 16.6 | | | 16.6 | | 42.6 | 36.8 | 2 | | | 4 | 4 |
| STINGRAY | | | | | | | | | | | | | | | |
| HAMMERHEAD | | | | | | | | | | | | | | | |
| TOTAL MHs | 2 | 52 | 34.6 | 16.6 | 0 | 0 | 16.6 | 0 | 42.6 | 36.8 | 2 | 0 | 0 | 4 | 4 |

**Figure 4.2.1 Two-Week Snapshot of X-11 Job Shop Organization of Man-Hours for Three Parallel Availabilities.**

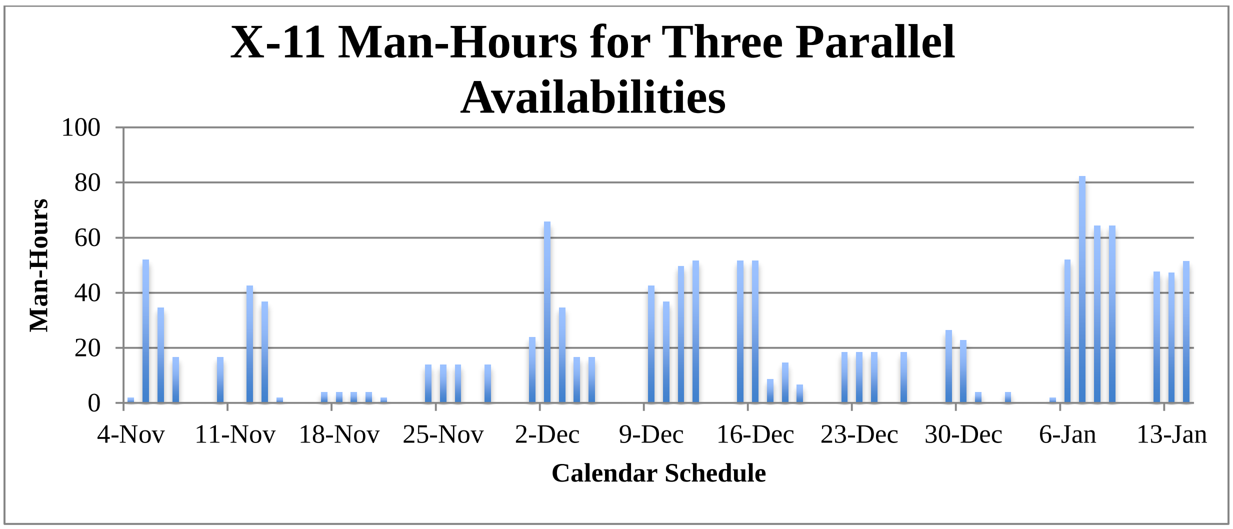


**Figure 4.2.2 Bar Chart of Total Man-Hours for Shop X-11 with Three Parallel Projects.**

For the paint shop, X-42, the procedures were slightly different due to the large number of man-hours to be accomplished by this shop. Instead of dividing the work into date ranges, one large date range for all paintwork was chosen. The assumption was made that all paint preparation and painting would be done from docking until undocking (weekends and holidays included). This is reasonable because prior to docking and after undocking are not ideal times for painting, and most of the man-hours are for underwater body painting that can only be accomplished with the cutter out of the water and in the climate-controlled enclosure. The total sum of man-hours was divided by the number of days in the range (55 days in this case) and then transposed to the following two availabilities (Figures 4.2.3 and 4.2.4).

| Weekends/Holidays | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4-Nov | 5-Nov | 6-Nov | 7-Nov | 8-Nov | 9-Nov | 10-Nov | 11-Nov | 12-Nov | 13-Nov | 14-Nov | 15-Nov | 16-Nov | 17-Nov | 18-Nov |
| x42 total hours/55 days | 0 | 0 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 |
| 2nd avail | | | | | | | | | | | | | | | |
| total sum | 0 | 0 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 |
| 3rd avail | | | | | | | | | | | | | | | |
| total sum | 0 | 0 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 |
| Divided by 6 ppd (total hours each person must work) | 0 | 0 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 |

**Figure 4.2.3 Two-Week Snapshot of X-42 Job Shop Organization of Man-Hours for Three Parallel Availabilities.**

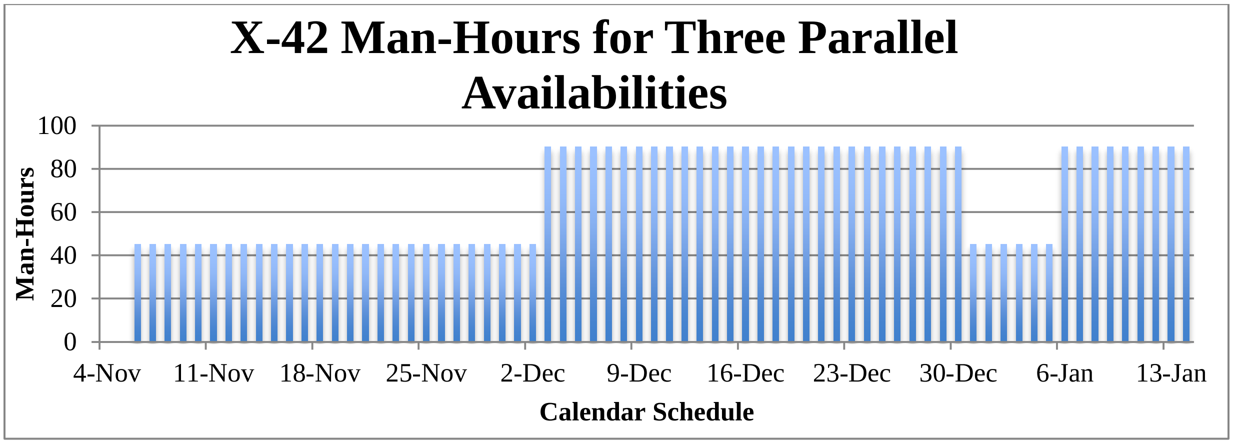


**Figure 4.2.4 Bar Chart of Total Man-Hours for Shop X-42 with Three Parallel Projects.**

After compiling the data for every job shop, all of the job shops were combined together. All of the hours were summed up for each day and then divided by 25.1 and 22.2 people per day (CG Yard estimated number of resources needed per day) to get the amount of hours per person per day. It was assumed that the trade labor needed for each day would be determined by the shop foremen so the labor could be divided equally into the designated number of laborers. However, the number of laborers per shop could be calculated by taking the total job shop hours for each day and dividing them by an 8-hour shift. For weekend and holiday work the total man-hours were divided by six (the predetermined number of paint shop workers to be utilized each overtime day). The man-hours per job shop were then plotted along the schedule, with job shop hours stacked on top of each other as done by NASSCO in their pipe-shop loading study. The hours per person per day were also plotted over the schedule to see which days went over an 8-hour shift. These finals steps were completed for one, two, and three availabilities.

### 4.3 Level-Loading a Single Job Shop

As they become available, the CG Yard provides actual man-hours expended for each job shop. Currently, only CGC IBIS' final cost report with man-hours is available. Other data for the STINGRAY, HAMMERHEAD, BLUEFIN, and POMPANO are available such as final cost, schedule delays, and progress notes. These results will be examined in the discussion section. The actual man-hours for CGC IBIS were compared to the estimated man-hours to determine the major differences. As this is just a single data point, a statistical analysis cannot be conducted. However, the actual man-hour data can be used to determine which job shop would benefit from level-loading the workload. This can be done by looking at the actual versus estimated man-hours as well as the initial loading of each job shop, determine which job shop incurs the most overtime hours or greatest variability of workday hours over the span of the project timeline (with three availabilities in parallel), and re-sequence the work of that individual shop with consideration to the updated WBS and other reasonable sequencing changes. The combinations of allowable sequencing in a project with this many subtasks are quite large, so this analysis will only cover one such sequencing option. Also, in re-sequencing one job shop to reduce the overall impact of overtime hours on the laborers, it is assumed that all other job shop sequencing would be impacted. Ideally, all job shops would be level loaded across the entire project. Due to the limited scope of this study, however, only one job shop will be analyzed.

## 4.4 Results

Spreadsheet modeling opened up doors for analysis that could not have been done with planning documents alone or within current planning software. The analysis provides a visual representation of project loading and gives the planners and estimators greater control over program modeling. The results for the loading of the projects were done in an iterative manner in order to see how adding an additional cutter to the workload would impact total man-hours and man-hours per person per day. CGC IBIS' maintenance availability began on November 4th, 2014 and was scheduled to end on January 14th, 2015. In this date range, CGC STINGRAY and CGC HAMMERHEAD are scheduled to begin their maintenance availabilities. The dates overlap 46 and 9 calendar days respectively. The loading of man-hours for one availability is fairly straightforward and reasonable to manage as work is not being done in parallel, and therefore resources are not being absorbed into other projects. The total daily and per person man-hours are shown in Figure 4.4.1 and displays that while working just one availability, the full 8-hour shift for the work crew is underutilized for the majority of the availability, with other days being slightly or well over two shifts.

ONE AVAILABILITY ONLY — Weekends/Holidays — CGC IBIS

| | 4-Nov | 5-Nov | 6-Nov | 7-Nov | 8-Nov | 9-Nov | 10-Nov | 11-Nov | 12-Nov | 13-Nov | 14-Nov | 15-Nov | 16-Nov | 17-Nov | 18-Nov |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| x11 | 2 | 52 | 34.6 | 16.6 | | | 16.6 | | 42.6 | 36.8 | 2 | | | 4 | 4 |
| x12 | | 6 | 4 | 4 | | | | | | | | | | | |
| x13 | 6 | 3 | 18 | 10 | 0 | 0 | 10 | 0 | 10 | 4 | 0 | 0 | 0 | 0 | 0 |
| x14 | 2.0 | 10.5 | 10.5 | 10.5 | | | 10.5 | | | 10.0 | 10.0 | | | 10.0 | 10.0 |
| x21 | 10.94 | 0.94 | 38.1 | 26.05 | 0 | 0 | 26.09 | 0 | 58.09 | 14.59 | 6.19 | 0 | 0 | 6.19 | 6.19 |
| x22 | 0 | 8 | 3.5 | 3.5 | 0 | 0 | 3.5 | 0 | 3.5 | 6 | 10.7 | 0 | 0 | 10.7 | 10.7 |
| x23 | 15 | 9 | 54 | 25 | 0 | 0 | 25 | 0 | 25 | 38 | 12 | 0 | 0 | 12 | 12 |
| x24 | | | 18 | 3 | | | 3 | | 3 | 3 | | | | | |
| x31 | 10 | 18 | 64 | 27 | 0 | 0 | 27 | 0 | 55 | 9 | 2 | 0 | 0 | 2 | 2 |
| x32 | 8.9 | 0.9 | 17.1 | 17.05 | 0 | 0 | 17.05 | 0 | 17.05 | 5.3 | 0.9 | 0 | 0 | 0.9 | 0.9 |
| x33 | | | 8 | | | | | | | | | | | | |
| x41 | 0.56 | 0.56 | 25.26 | 25.26 | 0.00 | 0.00 | 25.26 | 0.00 | 25.26 | 5.76 | 4.56 | 0.00 | 0.00 | 4.56 | 4.56 |
| x42 | 0 | 0 | 45.1 | 45.1 | 45.1 | 45.1 | 45.1 | 45.1 | 45.1 | 45.1 | 45.1 | 45.1 | 45.1 | 45.1 | 45.1 |
| x43 | 15.70 | 20.70 | 89.10 | 44.10 | 0.00 | 0.00 | 44.10 | 0.00 | 44.10 | 21.10 | 5.03 | 0.00 | 0.00 | 5.03 | 5.03 |
| x61 | | 2.5 | 5.5 | 5.5 | | | 5.5 | | 3 | 2.3 | 6.3 | | | 2.3 | 2.3 |
| x64 | | | 8 | | | | | | | 1.2 | 1.2 | | | 1.2 | 1.2 |
| x65 | | | | | | | | | | 1.2 | 1.2 | | | 1.2 | 1.2 |
| x66 | | | | | | | | | | 1.2 | 1.2 | | | 1.2 | 1.2 |
| Total | 70.8 | 132 | 443 | 262.5 | 45.1 | 45.1 | 258.6 | 45.1 | 331.6 | 204.9 | 109 | 45.1 | 45.1 | 107 | 107 |
| /25 ppd | 2.821 | 5.25 | 17.6 | 10.46 | 7.52 | 7.517 | 10.3 | 7.52 | 13.21 | 8.163 | 4.32 | 7.52 | 7.52 | 4.24 | 4.24 |
| /22.2ppd | 3.189 | 5.94 | 19.9 | 11.82 | 7.52 | 7.517 | 11.65 | 7.52 | 14.93 | 9.23 | 4.89 | 7.52 | 7.52 | 4.8 | 4.8 |

**Figure 4.4.1 Total and per person man-hours for one availability, the CGC IBIS.**

Figure 4.4.2 clearly shows the variable loading of man-hours over the course of one availability. Comparing workday loading, the maximum load is nearly 450 man-hours, while the minimum load is slightly over 50 man-hours per day. Weekends, when the paint shop will be using six laborers, stay constant at about 50 man-hours per day.

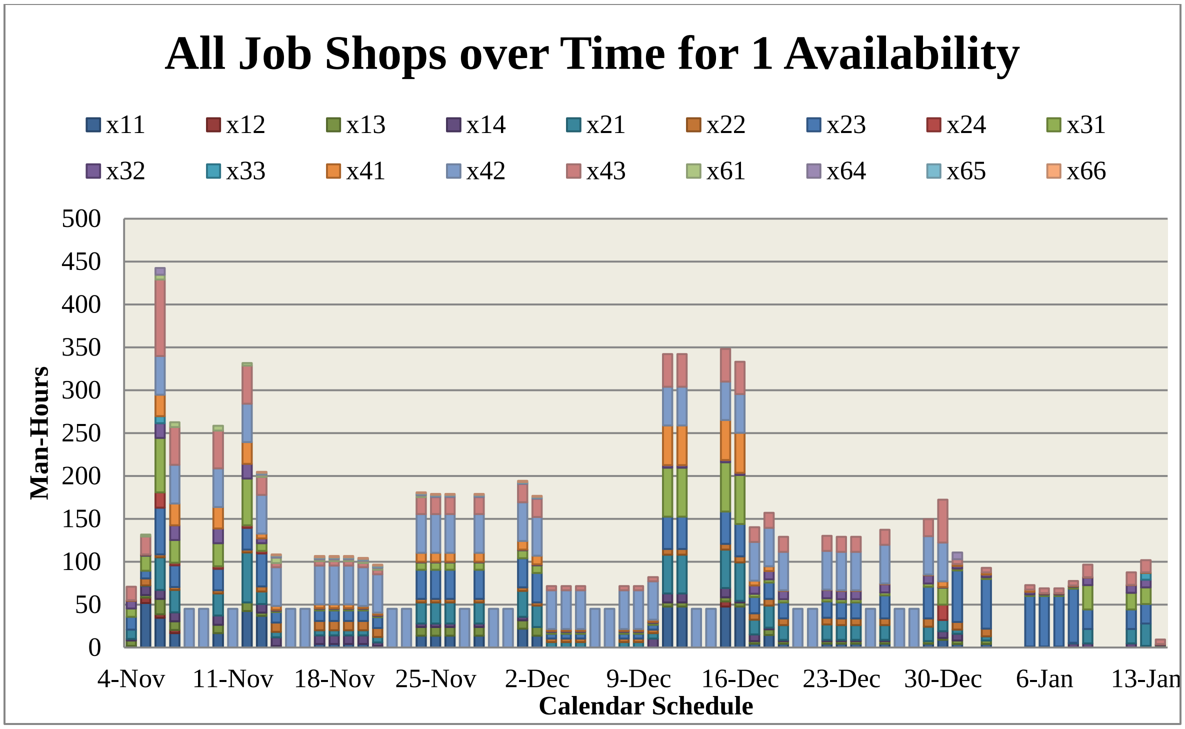


Figure 4.4.2 Total man-hours for one availability, the CGC IBIS.

Figure 4.4.3 compares the two different manning scenarios' loading conditions. The labor hours per person vary greatly from zero to 20 per day.

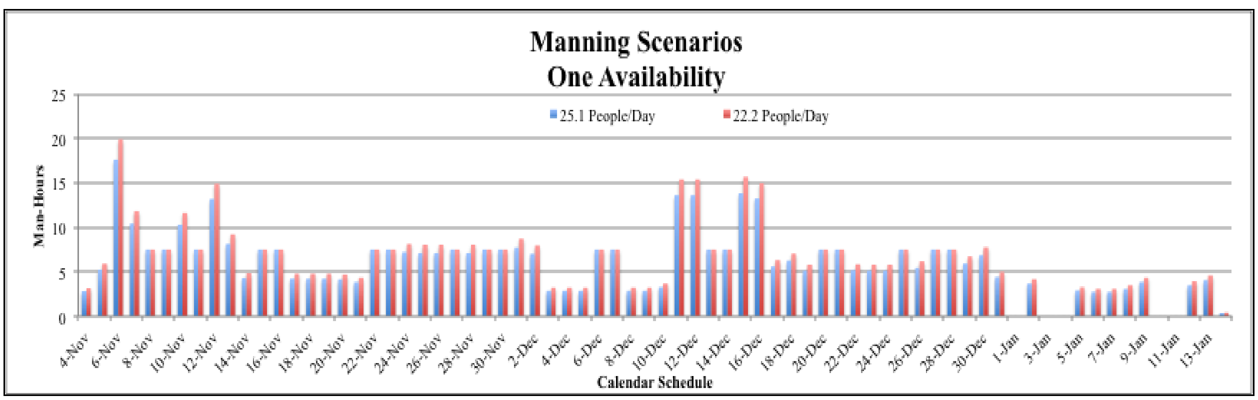


Figure 4.4.3 Manning Scenario Comparative Graph for One Availability.

The minimum, maximum, average and standard deviation for the different manning scenarios are presented in Table 4.4.1. The minimum hours, found on weekends and holidays when paint shop work has stopped, is zero for one availability. The maximum hours extend over three standard deviations above the mean for both scenarios.

| Manning Scenario | Minimum Hours | Maximum Hours | Average Hours | Standard Deviation |
|---|---|---|---|---|
| 25.1 People | 0 | 17.631 | 6.017 | 3.521 |
| 22.2 People | 0 | 19.935 | 6.544 | 3.891 |

Table 4.4.1 Descriptive Statistics for Loading of One Availability.

As the second availability CGC STINGRAY overlaps with CGC IBIS, the man-hours mid-way through the availability represent the conditions for parallel loading of two projects. The spike in man-hours as seen in Figure 4.4.4 and Table 4.4.2 show that what would normally be a one-shift workday, now requires at least two shifts.

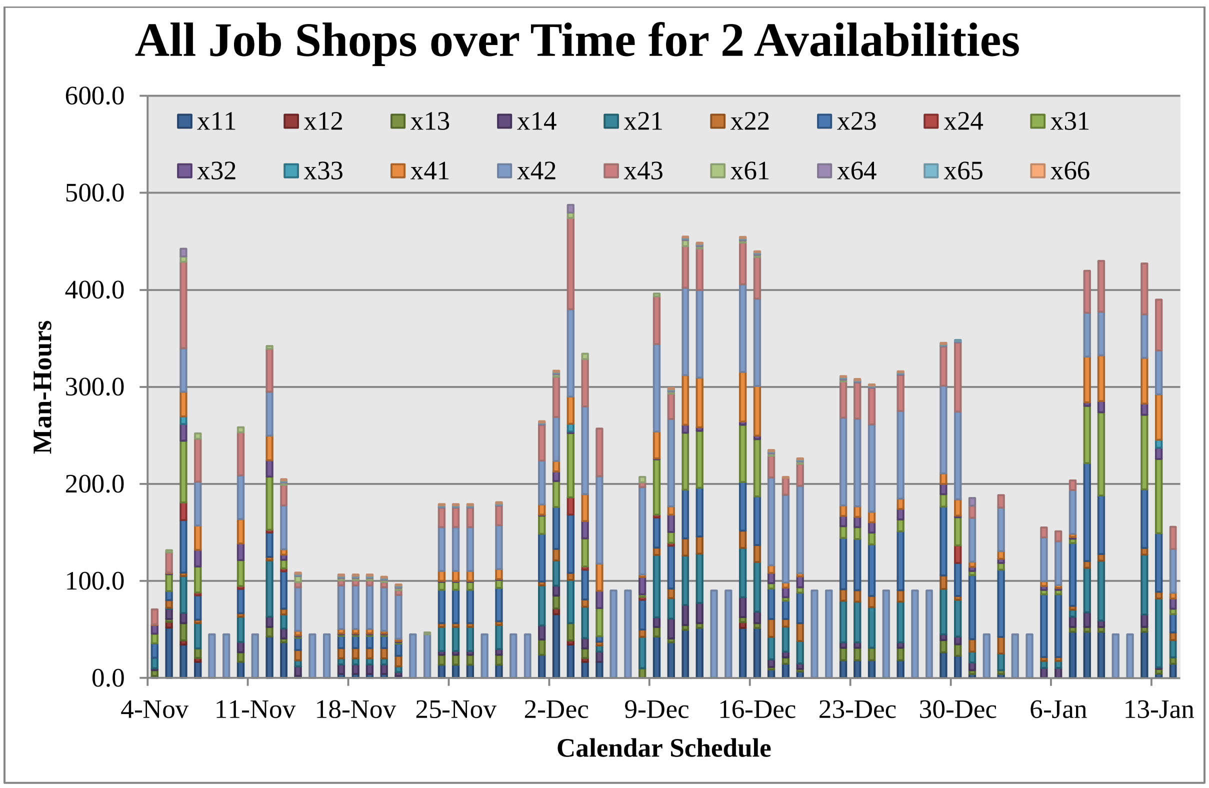


Figure 4.4.4 Total man-hours for two availabilities, the CGC IBIS and CGC STINGRAY.

| Manning Scenario | Minimum Hours | Maximum Hours | Average Hours | Standard Deviation |
|---|---|---|---|---|
| 25.1 People | 2.8 | 19.4 | 10.5 | 4.404 |
| 22.2 People | 3.2 | 22.0 | 11.4 | 4.656 |

**Table 4.4.2 Descriptive Statistics for Loading of Two Availabilities.**

With the third availability CGC HAMMERHEAD overlapping with CGC IBIS and CGC STINGRAY, the man-hours represent the conditions for parallel loading of three projects. The man-hours toward the end of the first availability trail off as the paint shop ends work on CGC IBIS, but just one week later is back up to two project's worth of work as CGC HAMMERHEAD's paint work begins. The maximum hours per person per day now increases significantly as three projects are being conducted in parallel. The average workday shift is now over 11-hours, well above the one eight-hour shift planned for the program. This is seen in Figure 4.4.5 and Table 4.4.3.

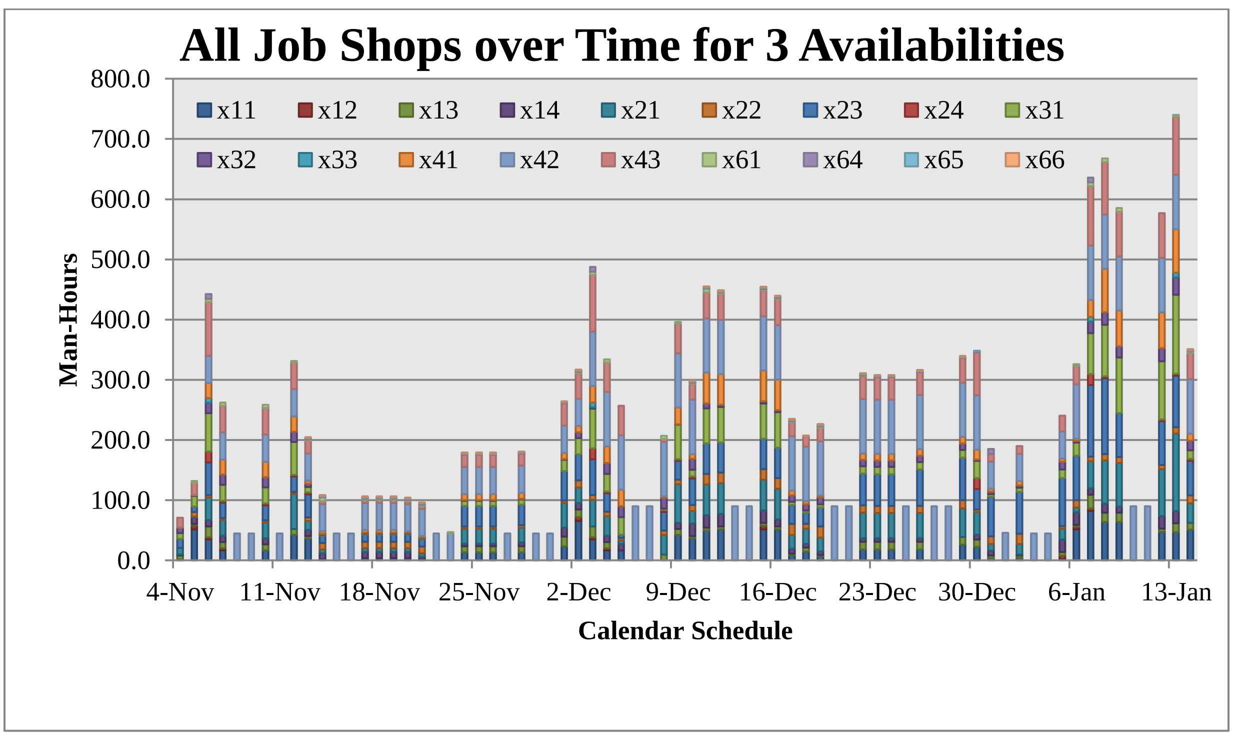


**Figure 4.4.5 Total man-hours for three availabilities, the CGC IBIS, CGC STINGRAY, and CGC HAMMERHEAD.**

| Manning Scenario | Minimum Hours | Maximum Hours | Average Hours | Standard Deviation |
|---|---|---|---|---|
| 25.1 People | 2.8 | 29.5 | 11.7 | 5.64 |
| 22.2 People | 3.2 | 33.3 | 12.7 | 6.37 |

**Table 4.4.3 Descriptive Statistics for Loading of Three Availabilities.**

After final closeout of CGC IBIS' availability, the final cost report was obtained with actual man-hours expended. The CG Yard broke down the final costs into the two main funding strings used in the Coast Guard: AFC30 and AFC45 funds. AFC30 funds are shipboard operating and maintenance funds that are given to each cutter to use in a given fiscal year. AFC45 funds are Naval Engineering funds and are designated for depot-level maintenance projects like drydock and dockside availabilities. Comparing the subtask man-hour estimates (AFC30 and AFC45 combined) to the total actual man-hours, the CG Yard underestimated the total man-hours required for completing the project. Looking at the project totals, 530 additional hours were required over the original estimate (Table 4.4.4). This is particularly concerning given the loading conditions analyzed were already showing overload of the expected workforce per day.

| | 11 | 12 | 13 | 14 | 21 | 22 | 23 | 24 | 31 | 32 | 33 | 41 | 42 | 43 | 61 | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Actual Man-Hours | 798 | 36 | 171 | 147 | 828 | 250 | 610 | 25 | 841 | 228 | 0 | 410 | 2681 | 829 | 829 | 8682 |
| Estimated Man-Hours | 566 | 20 | 179 | 220 | 816 | 254 | 1259 | 48 | 643 | 230 | 16 | 431 | 2478 | 884 | 108 | 8152 |
| Difference | 232 | 16 | -8 | -74 | 12 | -4 | -649 | -23 | 198 | -2 | -16 | -21 | 203 | -55 | 721 | 530 |

**Table 4.4.4 Total Actual Required Man-hours Compared to Original Estimated Man-hours.**

Looking at the major differences between actual and estimated man-hours, job shop X-61 (or support services) is seen to have the largest underestimation of man-hours. This is a job shop that does not work on site with the cutter, but rather in the management office. Work sequencing for this job shop is also less of a concern, as work on the cutters will not necessarily stop for support services. Therefore, the loading of this job shop is not as important as the analysis of a “hands on” job shop. The next largest underestimation of man-hours is in job shop X-11, shipfitting. Level-loading of a shop can be thought about in multiple ways. The most ideal way to load a job shop would be to have the same number of hours for a set number of workers for the entire duration of the project. This would create the most predictable and flexible schedule. By taking the total number of hours estimated for the X-11 job shop and dividing it by the 48 working days in the project timeline, an 11.8-hour workday can be planned to complete all of the work for one availability. By overlapping the second and third availabilities, a step-wise workload is created (Figure 4.4.6). This does not create a level-load of the job shop over the course of the availability. However, after adding the total number of man-hours given this overlapping scenario and again dividing by 48 working days, a level-loaded project timeline can be achieved with a 21-hour workday (Figure 4.4.7).

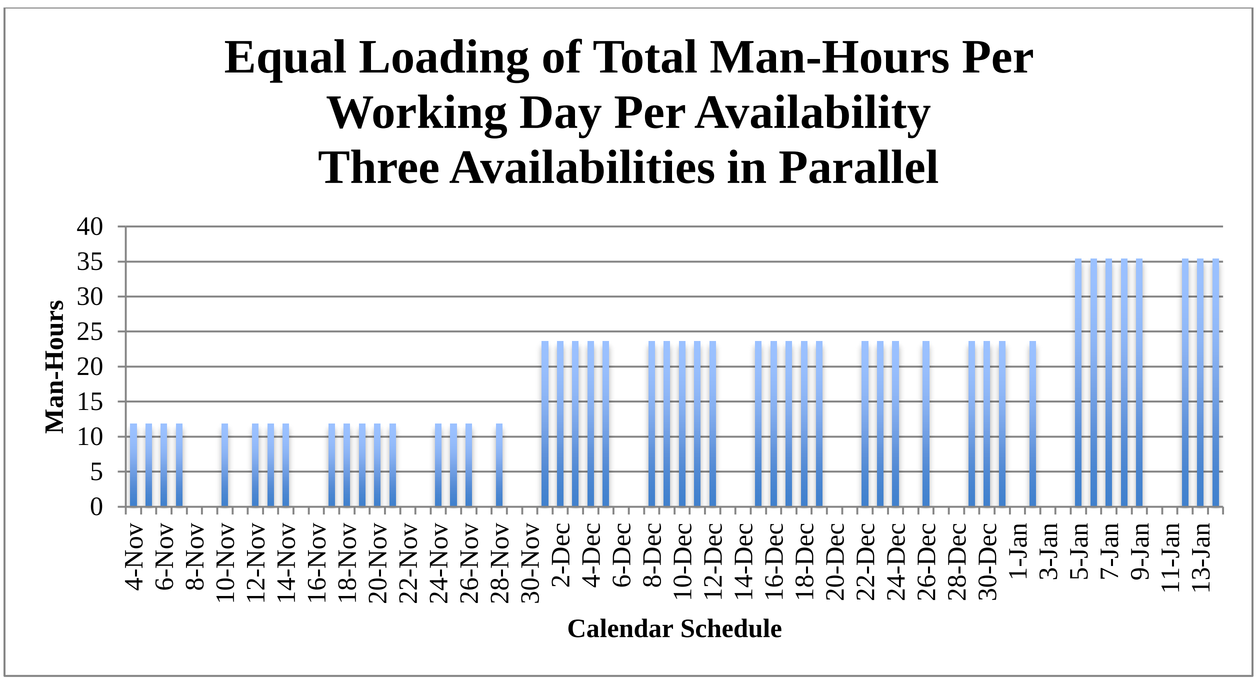


Figure 4.4.6 Stepwise Loading of Man-Hours after Level Loading One Availability.

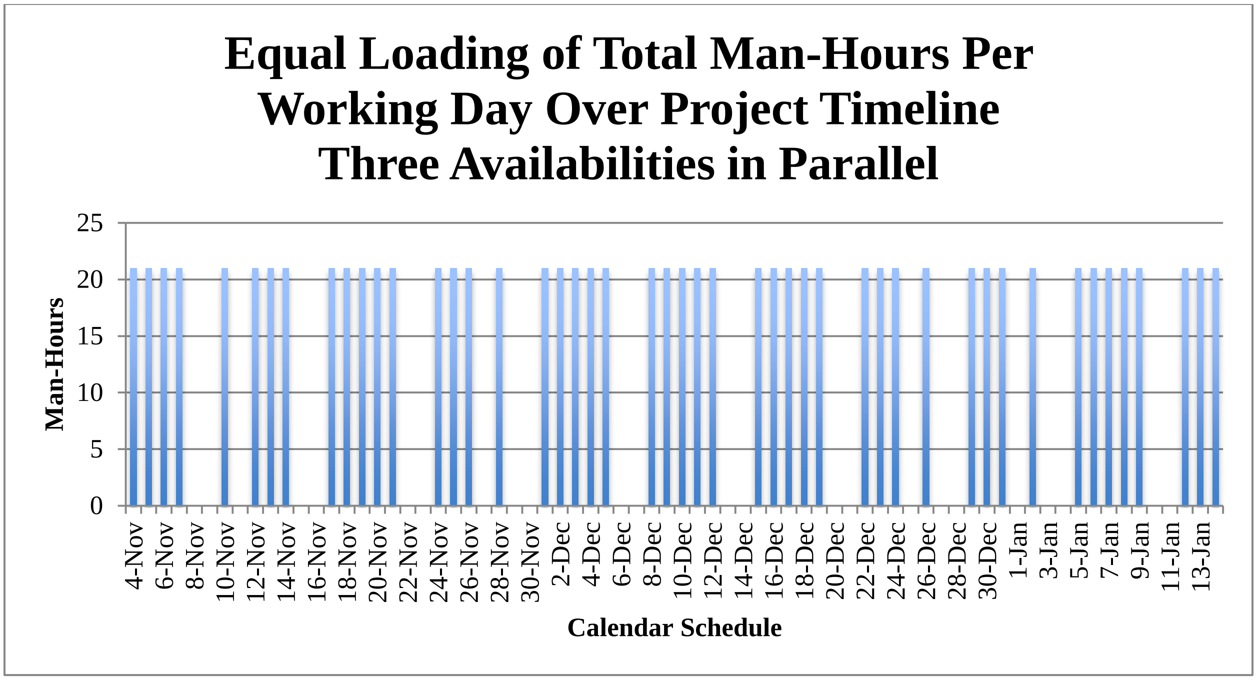


**Figure 4.4.7 Equal Loading of Three Availabilities' Total Hours over Project Timeline.**

This equal loading over the project timeline may be realistic for a production line that has one task, but it is not realistic for sequence dependent work. So in order to attempt to level-load a job shop that has set deadlines for subtask completion, it is more reasonable to level-load across shorter periods of time rather than the whole project timeline. A single project was level-loaded across weekly timelines and then carried across three projects in parallel. The results for level-loading a shop can be seen below in Figures 4.4.8 and 4.4.9 When compared to the original sequencing of work, the level-loaded schedule has more moderately loaded workdays and several consecutive days of equal loading, with the exception of the docking days.

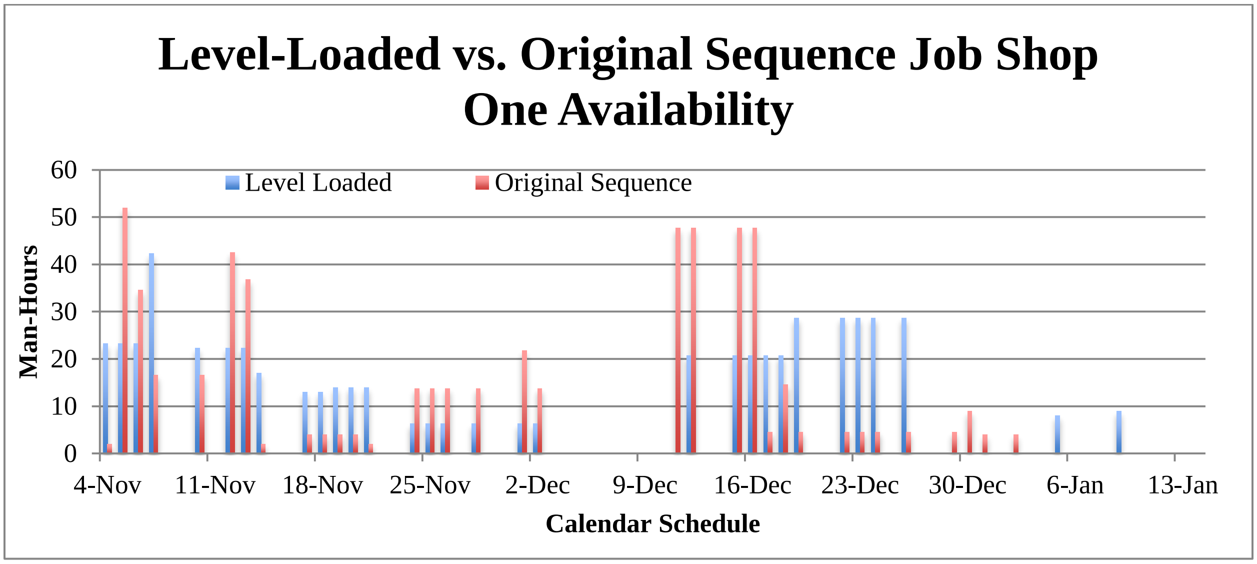


**Figure 4.4.8 Level Loading of One Availability over Short Time Periods.**

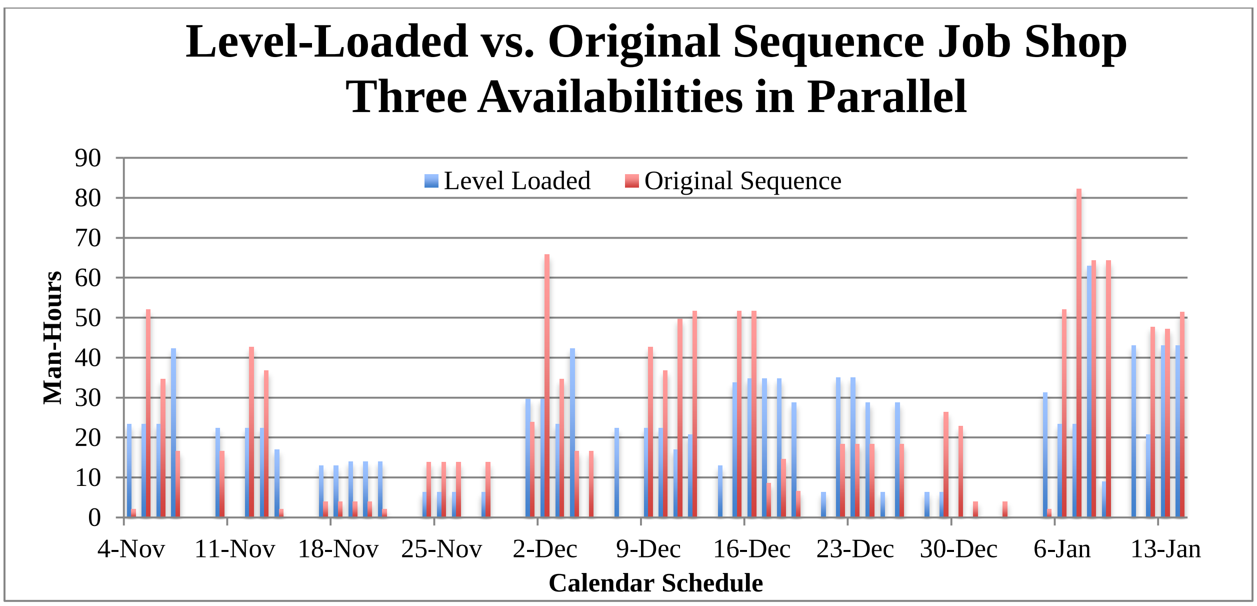


**Figure 4.4.9 Level Loading of Three Availabilities over Short Time Periods.**

By minimizing heavy-loaded (>40 hours) and light-loaded (<8 hours) days for a single job shop, resources will not need to fluctuate as much on a day to day basis. Also, in the event of excess work being added to a single day, the chance of needing overtime or additional laborers is decreased because of the scheduled moderate workload.

Weekly progress meeting notes from the first five availabilities, along with estimated and actual completion dates were retrieved from Contract Workbook Database. Actual man-hours for the second through fifth availabilities were not available from the CG Yard due to long closeout times. Table 4.4.5 lists the availability actual and estimated start and end dates as well as problems encountered during the availability.

| Cutter | Estimated/Actual Start Date | Estimated/Actual End Date (Total # Weeks) | Problems |
|---|---|---|---|
| CGC IBIS | 04 November | 14 January (10 weeks) | -Sequencing Rework<br>-Paint Preparation |
| CGC STINGRAY | 30 November/<br>01 December | 11 February (10 weeks) | -Delay Start due to weekend<br>-Many Holidays<br>-Showed Potential for Delay due to Paint which backed up other shops<br>-Winter Weather issues cause undocking 1 day early |
| CGC HAMMERHEAD | 05 January | 24 March (11 weeks) | -STINGRAY Delivery & BLUEFIN Arrival Delaying HAMMERHEAD work<br>-Yard Closure due to Weather<br>-Paint Rework (external) |
| CGC BLUEFIN | 01 February | 08 April/<br>15 April (10 weeks) | -Winter Weather/Wind Delays Docking 1 day<br>-Lost Production Hours & Days due to Winter Weather Yard Closure<br>-Extensive Structural Repairs delay Paint Shop<br>-Higher Priority Cutters Using Labor Resources<br>-Realign Both Main Diesel Engines<br>-Cracked Pipes due to Freezing Weather after Undocking<br>-Damage from Blast Grit (Rework) |
| CGC POMPANO | 09 March | 17 May (proposed 10 weeks) | -Paint Rework<br>-Growth Work due to Previous Avail. Improper Sequencing |

**Table 4.4.5 Progress Notes Detailing Start/End Dates and Problems Encountered for First Five Cutters.**

Table 4.4.6 details the newest changes to the WBS for the fifth availability, CGC POMPANO. The changes or additions compared to CGC IBIS' WBS are color coded in the full

WBS in the Appendix (Figure A.24). Several changes were made based on lessons learned and re-sequencing of work item tasks.

| **Pushed Back (Later Date)** | **Pushed Up (Earlier Date)** | **New Item Added** |
|---|---|---|
| Install Lagging | Mast Interference Removal | Remove Equipment Prior to Docking |
| Final Walk-Through | Mobilize Blast Equipment | Clean Grit Blast Material |
| | Remove Bilge Interferences | Complete Surface Preparation |
| | Installations | UT Shots/Hotwork |
| | Testing | Paint Bilges |
| | Clean-Ups | All Paint Work Complete |
| | Dock/Sea Trials | |

**Table 4.4.6 Items Updated on WBS for CGC POMPANO.**

## 4.5 Discussion

The results above show a progression of project complexity both in the planning and execution stages of the Bow to Stern Program. With the results of the one-availability scenario, it is easy to see pockets of light and heavy workloads. The daily workload is reasonable, showing on average a six-hour workday. The minimum workday load is zero which correlates to weekends when paintwork is not happening. The maximum workday load is 17.6 hours (19.9 hours). This occurs on the day that CGC IBIS is docked. Normally docking days are very long and require all-hands to be available. A typical docking evolution can take several hours to prepare the cutter, which includes removing liquid loads, brows, or other unnecessary equipment like small boats. The docking of an 87’ cutter is done with a cradle and a crane. This specific type of docking evolution is much faster than other types of docking, but can still take several hours and delays can occur due to weather conditions like wind and ice or tides and currents.

Post docking activities include setting up all protective measures, enclosures, scaffolding, and hooking up services (water/electrical) for tools. Blasting of the underwater body typically begins the day of docking as well. All of these events added together, with time waiting for everything to happen sequentially, can add up to an 18-hour day quite easily. Other pockets of heavy workloads are the week following docking and about a week and a half prior to undocking. There are approximately five days that have each person working 10-15 hour shifts. Following docking there are many removals of interferences and also of major components such as propellers, shafts, rudders, and any other removable parts that will be worked on in an offsite-shop. During this time, blasting of old paint can take several days or weeks and subcontractors and CG Yard workers are on the vessel inspecting and cleaning tanks and bilges. Prior to undocking, all of the pieces must be reassembled and re-inspected prior to acceptance. The sequencing of these big man-hour consumers are fairly fixed and can only be level-loaded by adding more resources or using more overtime hours in that time range. Given that only six total days (out of 72) would require double shifts, this does not seem too difficult to manage.

By adding the CGC STINGRAY's availability schedule onto CGC IBIS' schedule, the scenario becomes much more challenging. The average workday shift per person becomes 10-11 hours. The workload for the job shops is essentially doubled with the entrance of the second availability and will never be reduced for the remainder of the four-year program. Approximately 30 of the 72 days in the time range would require 10 hours of work per person. Given that many of the 30 days are consecutive, this does not leave much room for overtime without the risk of burnout. This situation is only worsened when the third cutter, CGC HAMMERHEAD arrives, adding yet another layer of man-hours. Approximately 37 of the 72 days require 10 hours of work per person, with some days requiring up to 20 hours (22 hours for 22.2 people). The additional seven days appear at the end of the time range when CGC IBIS is being delivered. The delivery of the first availability on time is crucial to the CG Yard's reputation and all resources will be pushed into that cutter to make it happen. Many of CGC STINGRAY and CGC HAMMERHEAD's hours will likely be used for CGC IBIS' final push.

As seen with the level loading of job shop X-11, heavy and light loaded workdays are adjusted to level-loaded and moderate workloads for shorter periods of time (approximately one week). This is a more reasonable way to level-load sequence dependent work as opposed to level loading across a project timeline. By creating equal resource loading over multiple days, workers can adapt to more routine shifts and the crew composition will remain mostly constant. This reduces the need for overtime as well as overmanning and all the negative effects of introducing unfamiliar or unskilled workers to a project. Further analysis can be done to improve level loading if changes are made to milestone activities in the project like docking and undocking dates. The level loading process could also be used to optimize the time between cutter arrivals. The 30-day interval may have been chosen arbitrarily for this program, but as seen with cutter deliveries and arrivals coming within one week of each other, this is not an ideal situation as it causes surging of resources.

As seen in Table 4.4.5, the first five availabilities have either made the 10-week timeline or exceeded it by 1 week. CGC IBIS met the 10-week schedule, but did face rework because the initial sequencing needed to be adjusted to circumstances not accounted for in planning. Some rework and additional work had to do with paint preparation methods in the lazarette as the space is extremely small and requires a smaller worker. The grit blast method was not adequate to prepare all areas, so hand tools (which require more time) had to be utilized. CGC STINGRAY had to accommodate some of the changes in sequencing discovered in the first availability. They were also the first availability to face issues with weather. Winter weather did not cause issues within the enclosure, but for getting the cutter back in the water. CGC HAMMERHEAD, being the third availability, took an extra week to complete due to the weather closing or delaying production, job shops overcoming their first fully loaded availability (three ships in parallel, 1st cutter delivery), as well as the inflexibility in the schedule and having to complete paint rework. Surprisingly, the CG Yard workers were able to complete CGC BLUEFIN in 10 weeks (scheduled for 9) when this availability was plagued with more issues than CGC HAMMERHEAD, including reduced priority in the shipyard, growth work due to freezing temperatures after undocking, and activation of option items (engine alignment and hot work for structural repairs). The reason for overcoming these obstacles is due in part to new mitigation strategies like utilizing subcontractors on the engine room and lazarette bilge painting work items (over 100 hours of preservation given to subcontractor). CGC POMPANO received an updated WBS that incorporated all of the changes made in sequencing since CGC IBIS (Tables 4.4.6 and Figure A.24).

The current strategies implemented at the CG Yard to mitigate schedule risks include overtime, overmanning/surging, subcontracting work, improved efficiencies in tools for paint shop, and updating work sequencing. Scheduling overtime for one job shop for the duration of a four-year program was not the best course of action for the CG Yard. The scheduled overtime didn’t even have the added benefit of making the schedule more flexible. The literature shows that overtime in small doses is not a bad strategy, but to expect a small group of people to work overtime for four years straight is bound to cause burnout, low morale, and likely injury. Fluctuating resource loading (Figures 4.4.1, 4.4.3, and 4.4.4) supports the need for better level-loading of work to reduce the need for overtime and overmanning. The Navy, as well as other government organizations, has a long historical record of accepting ships with major discrepancies, requiring the shipyards to fix most, but not all issues (U.S. GAO 2013). The CG Yard also delivers ships to its customers with incomplete work items. The CG Yard, however, schedules follow up visits to complete the work so as not to delay a cutter's return to its operational duties. This added burden of traveling for overtime work would take resources away from future availabilities, requiring additional mitigation strategies to be implemented.

The CG Yard does not necessarily feel the impacts of the hiring and firing schedule due to the fixed nature of the workforce, but they may feel similar secondary effects when subcontracting out work items. Workers unfamiliar with the ship and shipyard personnel will need to come together to work in the same space, which may cause overcrowding, out of sequence work, and rework. Management also has less control over subcontractors and must work through their superintendent to pass along critical information. The positive outcomes of subcontracting work, particularly paint work for this project, are that it reduces part of the workload of the paint shop (100 man-hours out of 2,500 man-hours). The trouble with subcontracting the entire work item or other work item's coating tasks is that the workers would either need to work side by side or on alternating shifts. This could result in overcrowding and quality control issues if workers are trained differently. Due to the competing projects at the CG Yard and the differing priorities of the missions they carry out, resources are often taken from a lower priority vessel and given to another. This surging can take resources away from the 87' Bow to Stern Program or add resources to it when their priority is increased. With the inflexible schedule and the small size of the 87' cutter, surging can be difficult to implement properly.

The tools originally used for preparing surfaces in tight spaces like the lazarette and stern tube were not sufficient to get the quality of bare metal needed to paint. The extension of this process affected the underwater priming of the hull for the very important task of side scanning the cutter. In order to reduce the process time of this task, a new 90-degree rotating blast head was used for CGC BLUEFIN. There are also several different techniques for preparing and coating surfaces. The 87’ Bow to Stern Program uses grit blast as its preparation method. Water jetting is another technique that is utilized on other cutters. Paint coatings can be applied with a spray or roll-on technique. The reason for using one technique over another may lie in the cutter class differences, the environmental regulations, or in the training of the individuals performing the work. It can be assumed that the first two reasons are not going to change. Learning new techniques is an option, but also a big challenge at the CG Yard. If the capital to invest in a new painting tool is available, the laborers may not be willing to learn how to use it or it may take them a long time to learn how to use it. Due to the long tenure of many of the CG Yard workers, many do have an unwillingness to try new techniques or technologies. Finding the right motivational methods in this case is challenging, especially in the middle of a high-tempo project.

Making changes to a project schedule is a crucial step in project management. Following the steps of Plan, Do, Check, Act (PDCA) verifies that changes are beneficial. PDCA was implemented from the start of IBIS’ availability to POMPANO’s availability in the WBS. Some items were moved up in the schedule, others were moved back, and some tasks were added to the sequencing because of their importance. Mast and bilge interferences, preparation set-up, and initial shaft alignments were all moved up in the first part of CGC POMPANO’S schedule. Putting mast work on the first day was wise as this work can be done when the cutter is still in the water, freeing up time later for critical path work like paint preparation and coating. Interference removal and alignments were also pushed up because they are tasks that must be completed prior to painting work items and can be done immediately following docking. Some new tasks added to the WBS at the beginning of the availability include equipment removals, technical representative visits, and clean ups needed before another large task can begin. The addition of these tasks, though they might not seem overly important, probably had valuable lessons learned in the first four availabilities. For example, the preparation of the lazarette and stern tube was moved up in the schedule because the dust created by this process needed to be cleaned up before a prime coat was applied to do the side scan of the cutter. In the middle of the schedule, the new tasks added are bilge preparation, ultrasonic thickness measurements (UT shots), all hot work, painting of bilges, installations, more technical representative visits, and final touch-ups. The big items worth mentioning here are the UT shots, hot work, and bilge paint. The large extent of structural repairs on the hull and in bilges on the CGC BLUEFIN almost caused the project to reach its tipping point. By giving more specific dates to tasks, the CG Yard has better control to adapt to conditions found. The UT shots determine where new steel or weld patches (clad welding) needs to be added, the hot work must be completely finished before any painting occurs, and in the event that paint is behind due to structural repairs, the paint subcontractor will be penciled in to absorb the engine room and lazarette work items. Some items that were pushed up toward the end of the availability include installations, testing, cleaning, and trials. These items were likely pushed up because their sequence didn’t impact other items (some installations/tests) or it was found that they didn’t take as much time as first estimated (trials). Two items were pushed back at the end of the schedule, lagging installation and final walk-through because they can be done after undocking when the majority of the critical path items are complete. The bulk of the moved or added tasks made the schedule more efficient and less crowded during paint preparations and coatings. It did not however, directly influence the time and labor constraints that the paint shop still has to work around (with the exception of utilizing subcontractors). The following section will cover the pros and cons of other potential strategies for improving the schedule, with special attention on the paint shop.

The manning scenarios, utilizing 25.1 (or 22.2) people per day and 6 painters per weekend/holiday, were used as an estimate for the purposes of looking at the loading of the project. The CG Yard is very flexible in how they utilize their resources and the total number of laborers can fluctuate each day and within each job shop. The job shops had the flexibility, in the case of the Bow to Stern Program, to utilize anywhere between one and ten workers per job shop in order to complete daily tasks. Considering this large swing in resources, the man-hour results listed above (per day) could be high or low, but were generally a mid-point estimate based on project expectations. The results do however, show that level-loading the project given the current sequencing is not possible without fluctuating labor resources or using additional strategies to cut down the number of man-hours required to complete the work package. By conducting the level loading of job shop X-11 over small time windows in the project timeline, the large variability of resources needed per day can be reduced. Doing a complete level-loading analysis for this program by hand, let alone for all concurrent shipyard projects, is cumbersome. The following section will discuss smarter ways for the organization to overcome the challenges associated with level-loading job shops.

# CHAPTER 5

# DECISION SUPPORT TOOLS

## 5.1 Mitigation Strategies

The goal of the 87’ Bow to Stern Program is to minimize the total project duration so that the 87’ mission is not compromised due to long maintenance availabilities. As such, the use of expensive mitigation strategies is considered appropriate to meet this goal. However, there is a delicate balance that must be achieved given the nature of the industrial yard, its employees, and most importantly, the consequences of using mitigation strategies. Rework, the biggest threat to the schedule, can be caused by out of sequence work, poor workmanship, or a material quality issue. Change orders are unforeseen tasks added to existent work items. Option items are part of the original scope of work due to their anticipated activation from known problems, but are not considered new work. Scope changes add new work items due to technology improvements or new standards/regulations. Schedule pressure is an immeasurable phenomenon that occurs as a project nears a milestone or completion deadline.

The CG Yard’s unionized workforce can present challenges to managers when it comes to utilizing standard mitigation practices found in non-unionized commercial shipyards. The laborers are government employees, who after one year in the position are guaranteed employment. Because their employment is fixed, the workers enjoy and may even push for overtime as it pays time and a half.  Everything from overtime hours, the number of new hires, required breaks and holidays and many other issues require bargaining. It can be difficult for the management to stay within the union guidelines and motivate the workers. The plan to allow shop foremen to run the 87’ Bow to Stern sequencing of CGC IBIS gives them this motivation, as they are given autonomy. However, with this freedom, workers may move too quickly which can cause rework if done out of sequence. Furthermore, inter-shop disputes over sequencing and miscommunication about the “plan” could detract from project progress. This forces management to keep a close eye on the proposed WBS schedule and the work progress on the cutter as well as the actual man-hours expended.

Some different and new mitigation strategies that the CG Yard could consider for improving paint shop loading and the 87’ Bow to Stern Program include cross training job shops (multiskilling), implementing Jobshop Lean, acquiring improved scheduling software with additional capabilities, and adopting better management techniques.

Single skill work within job shops is still the norm at the CG Yard and several of the assumptions made in the literature do not apply to this organization. However, other job shop personnel that are less occupied could acquire paint certifications or become painter helpers. This would be particularly useful for younger hires that are still apprenticing in their trades to acquire various skills (Burleson 1998). There would be limited additional cost to the CG Yard as they would be using currently employed personnel, eliminating the delay and familiarization requirements usually associated with new hires. This would boost the roster so a work rotation (with fixed shifts) could be established and ultimately reduce overtime for the strapped job shop.

Jobshop Lean can be implemented for all job shops with mobile equipment and tools, but is ideal for the paint shop. Paint equipment, like grit blast hoses, nozzles, barrels, compressors, paint, applicators, etc. can be staged at the two enclosures or in collocated structures. This will eliminate the need for equipment set up and breakdown each day. One major disadvantage to Lean implementation is the pushback to change, particularly in using smart technology for communicating (Mayer 2008). Getting each painter or even the lead painter to communicate via PDA or smart phone with their foremen for tasking and daily work progress would need to be introduced with some form of motivation.

Motivation can be difficult at the CG Yard, because incentives cannot be monetary in nature for unionized employees. High performance work system (HPWS) is a strategy that could help with motivating employees by promoting a rewarding work culture. HPWSs have been studied in large businesses (>100 people) and is a set of employee management practices that has key objectives of increasing an employee's control over their jobs and introducing practices to improve employee welfare through increased involvement and reward practices (Patel and Conklin 2010). These practices also optimize the utilization of worker's knowledge, skills, and abilities for the benefit of the organization. Essentially, HPWS creates human capital within a firm. The hope for the firm is to be able to select, develop, motivate, and retain these employees. HPWS is easily implemented and practiced in firms with greater levels of group culture. Group culture emphasizes the internal qualities of cohesion and trust, teamwork, greater job satisfaction and environmental flexibility. These qualities will positively influence retention and perceived labor productivity within the organization.

Figure 5.1.1 is a decision tree for management to use when considering implementation of strategies in response to (immediate need) or in prevention of (foreseen) schedule risk. In the event of rework, change orders, scope change or schedule pressure, managers must determine the number of man-hours and/or resources required to address the issue. If the crashed task duration exceeds what is available in the schedule, then a schedule extension is imminent. However, if there is room in the schedule to add work, then a strategy will need to be implemented to account for unplanned time and resources. For response strategies, overtime and overmanning are considered. Overtime, if used in moderation and with special attention to laborer fatigue and workmanship, can work well. If adding a shift becomes necessary, the workers should be assigned a single shift per day in order to be on a routine to increase job performance (Jamal &

Jamal, 1982). Night shifts and rotating shifts should be avoided, as they will negatively impact productivity. As overtime is implemented, the CG Yard should be recording overtime hours and the number of people assigned to work overtime. As Singh noted, the calculation of required personnel to fulfill overtime requirements is only reliable when considering efficiency losses (Singh 2003). The CG Yard should be tracking the hours of overtime work assigned for each day of each project (in man-hours), and log actual work completed (in terms of task hours) in an iterative approach to determine if there are efficiency losses. This data can then be used to better plan resource loading when overtime becomes necessary.

Overmanning, to include surging and hiring subcontractors, should also be handled with care. If the additional resources cause any sort of overcrowding, the strategy should be abandoned. For an 87' cutter the maximum is 20 people per cutter, but this number could vary by compartment and by type of work being completed. An experienced foreman or supervisor should assess these specific details. If an area can accommodate additional resources, the maximum number should be set, any additional personnel (whether from an outside project or subcontractor) should be chosen based on experience or familiarization with the cutter, and more supervision should be added. Supervision could be in the form of data collection or walk-throughs and does not necessarily have to be on-site, as that would cause overcrowding. Preventative strategies are best implemented before the schedule risk is a reality and not in the midst of the project. They include using new tools with decreased processing times, adding multiskilled workers or helpers, and implementing Jobshop Lean. These strategies require time to implement due to learning curves, training, or coordination. In the event these strategies are used in the middle of a project, it must be assumed that an additional amount of time be added to account for lost productivity. A major change is never advisable during a project, so easing new equipment, people, and procedures in over time is the best method so as to enact PDCA.

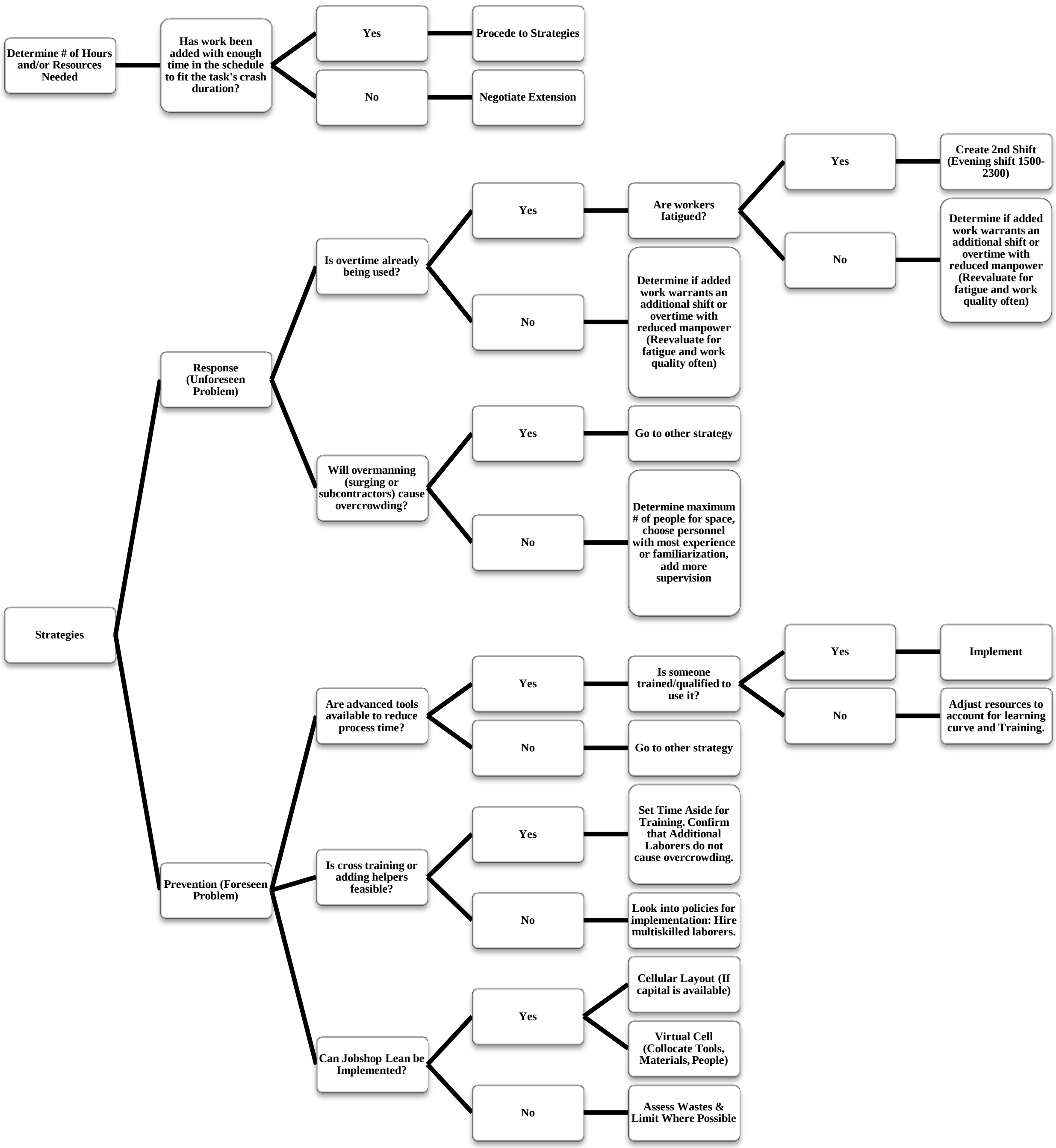


**Figure 5.1.1 Decision Tree for Selecting Schedule Risk Mitigation Strategies.**

## 5.2 CG Yard Efficiency Improvements

Investing capital into software improvements through system upgrades or adopting new software altogether would improve scheduling and hopefully eliminate a good amount of standard mitigation strategies needed. The CG Yard Schedulers currently use Oracle's Primavera P6 scheduling software (Primavera has additional project management software that extends beyond scheduling). They are also in the process of shifting to Microsoft Project software. Both software packages have capabilities to schedule projects and manage resources. The CG Yard uses this software to schedule each individual project. The major component that is lacking in the CG Yard's software is the use of an Integrated Master Plan (IMP). The IMP links all projects together by task, creating a big-picture view of all projects happening at a facility. Without an IMP linking all of the projects together, coordination and communication between projects is extremely difficult. This is particularly important for this facility as resources are shared across all projects. The CG Yard uses Earned Value Management (EVM) to track single project status throughout an availability, by measuring performance (actual and estimated) and using past data trends to predict the future impacts. Without a proper IMP in place, EVM data analysis is inadequate because it doesn't take into account the larger implications of other projects on the single project (Anderson and Upton 2012). The IMP replaces crisis management with proactive planning, establishes an overall critical path based on interdependencies, and allows for better resource management (Anderson and Upton 2012). Another benefit of the IMP is that it has the capability of level-loading job shops and can predict how resource movement affects resource needs in the future.

Another issue that the CG Yard faces with Primavera is the fact that it does not communicate well with other systems in use. Interfacing with or exporting to estimating databases, excel spreadsheets, or other applications is essential for producing quick results. Transposing information by hand into or out of software is cumbersome. Spreadsheet modeling could become a much quicker method of evaluating programs if all of the data can be shared and viewed across software platforms (namely Primavera's estimating and schedules with Microsoft Excel). There are several commercial scheduler software packages available in the marketplace, but the cost to acquire these is much higher than implementing upgrades or new tools into existent software. The cost doesn't just include material costs, it includes labor costs for learning, set up costs, and potential maintenance/service costs.

Simulation modeling is another computer-based tool in use by major shipyards throughout the world. Object-oriented simulation models can represent a shipyard's multitude of operations, people, and resources. Instead of investing large amounts of capital into untried strategies, simulation models can compare current and proposed systems to validate a new idea's worth. Simulation software, however, comes at a premium cost for the product and its services so would require an initial investment to get started. Simpler and more accessible simulation, like Monte Carlo Simulation, can be used for risk analysis. When historical data is not available, rough estimates of quantitative data can be modeled to produce a range of possible outcomes and the probabilities that they will occur (most likely, least likely, somewhere in the middle). This allows the user to see the consequences per risk level for their decisions. When examining the estimates provided by the CG Yard, one can see the problem with using discrete man-hour estimates instead of a distribution. Figures 5.2.1 and 5.2.2 show AFC30 and AFC45 work item man-hours respectively after the CG Yard adjusted their original Section B task duration estimates. These changes were made during progress on CGC IBIS as the CG Yard realized that many task durations were underestimated. The overall difference between the updated estimates and actual man-hours for AFC30 work items was only 36.75 man-hours.

The difference between the updated estimates and actual man-hours for AFC45 work items, however, was much more significant at 1369.5 man-hours. Another important observation is that the paint shop (X-42) used 137.25 man-hours more than estimated. This is a big red flag because there is no room given current resources to add more hours.

| AFC-30 Work Items | 11 | 12 | 13 | 14 | 21 | 22 | 23 | 24 | 31 | 32 | 33 | 41 | 42 | 43 | 61 | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Actual Man-Hours | 68 | 16 | 55 | 0 | 10 | 0 | 0 | 0 | 293 | 125 | 0 | 193 | 902 | 82 | 10 | 1752.3 |
| Estimated Man-Hours | 81 | 28 | 54 | 0 | 16 | 0 | 8 | 0 | 250 | 125 | 0 | 218 | 916 | 83 | 10 | 1789 |
| Difference | -13 | -12 | 1 | 0 | -6 | 0 | -8 | 0 | 43 | 0 | 0 | -25 | -14 | -2 | 0 | -36.75 |

**Table 5.2.1 AFC30 Work Items' Actual Required Man-hours Compared to Updated Estimated Man-hours.**

| AFC-45 Work Items | 11 | 12 | 13 | 14 | 21 | 22 | 23 | 24 | 31 | 32 | 33 | 41 | 42 | 43 | 61 | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Actual Man-Hours | 730 | 20 | 117 | 147 | 818 | 250 | 610 | 25 | 548 | 103 | 0 | 217 | 1779 | 748 | 819 | 6930 |
| Estimated Man-Hours | 604 | 20 | 308 | 416 | 1115 | 285 | 1549 | 48 | 438 | 105 | 16 | 233 | 1642 | 694 | 826 | 8299 |
| Difference | 126 | 0 | -192 | -270 | -297 | -35 | -939 | -23 | 110 | -2 | -16 | -16 | 137 | 54 | -7 | -1370 |

**Table 5.2.2 AFC45 Work Items' Actual Required Man-hours Compared to Updated Estimated Man-hours.**

Looking at the difference between the first set of task duration estimates and the updated estimates (Table 5.2.3), it is easy to see the uncertainty in the CG Yard's estimating techniques. The spreadsheet modeling conducted in Chapter 4 utilized the original estimates that were much lower than the updated and actual man-hours needed. The results of the spreadsheet model showed no room for additional hours with their planned resources and schedule, so one can see the problems the CG Yard will face by increasing their estimated man-hours by almost 24%.

| IBIS Availability Breakdown | | | |
|---|---|---|---|
| | Estimate (Updated) | Estimate (Original) | Actual |
| Total | 10088 | 8152 | 8682 |

**Table 5.2.3 Over- and Underestimations for Project Task Durations and One Data Set for Actual Man-hours for CGC IBIS.**

Using Monte Carlo Simulation in the estimating department at the CG Yard would be beneficial prior to inputting task durations into a scheduler. Other simulation modeling techniques and software referenced within the literature deal exactly with the structure of the 87' Bow to Stern Program and interface with Primavera. These methods, once marketed, would be an ideal addition to the CG Yard's software tools.

The CG Yard would also benefit greatly from the creation and implementation of a comprehensive program-grading rubric. This would provide a baseline for capturing a program's overall success. Project managers often fail to complete projects on time and on budget. Many do not realize that their project is no different from any other project; in fact they all run into the same problems (Cooper 1994). There are four reasons why project managers tend to not learn from past experiences: 1) belief that every project is different, 2) difficulty in understanding causes of project performance, 3) projects are transient, and 4) limited span and career path make transferring lessons learned difficult (Cooper et al 2002). The programs that the CG Yard adopts are well intentioned, but are usually planned without looking back to historical data to determine if the same methods succeeded in the past. This is in part due to incomplete data on past projects. With the high turnover rate of upper management with military transfers, program successes can be misrepresented. Military performance, particularly for the officers who make up the CG Yard management team, is measured annually and rarely looks back past the current period. This incentivizes an amplified assessment of recent years' initiatives and potential long-term achievements. Framing the impacts of the initiative as successful works for those initially involved, but loses its flare once passed onto the next person, resulting in reduced efforts to sustain the program. This could cause a program to look successful or not based on the newness or creativeness of the idea.

The CG Yard uses Contract Workbook Database, an online project management tool, to track project performance. The data for each project, if entered properly, includes percent growth, number of change requests, delays, budget overages and numerous other quantitative and qualitative descriptors. However, just like the problem with the Integrated Master Plan for the schedulers, the managers do not have a comprehensive overview of the program as a whole. Metrics quantify results through evaluation and production optimization. Operations are managed by adjusting, measuring, or calculating decisions, inputs, outputs, outcomes, and consequences. In order to collect data, a benchmarking and metrics program needs to be developed. Benchmarking evaluates the products, services, and work processes in order to help companies improve their performance by making policy and practice changes (Nasir et al 2012). Performance is determined by constraints as well as a performance index, or an all-encompassing view of the key performance indicators. There are three types of project performance: planned, perceived, and real (Lee et al 2005). Project performance factors must be comprehensive in order to ensure losses aren't incurred elsewhere (Moreno 2006). Many project cost improvements come from processes like teaming experienced people and staffing policies, while the other improvements come from external conditions such as fewer customer changes, better hiring conditions, and fewer problems with contractors and materials. Some policies and procedures that could be considered, and should be verified with past data, include taking on projects with more realistic timelines or a reduced scope, estimating off of the cutter (within the class) in worst condition, teaming estimators, schedulers, and foremen together to fine-tune schedules, and conducting a preemptive availability prior to the program start to get more realistic task duration estimates and work sequencing. This would give the CG Yard the time it needs to adapt its resources to accommodate the specific needs of the cutter class given the work package prior to starting the high-tempo program. The ability to model projects using past data creates best practices and lessons learned that could be brought forward for improved project management of future projects (Cooper et al 2002).

Applying management techniques or strategies for project improvement without understanding how they've impacted past projects can result in many wasted resources. Having a clear set of measures of effectiveness for every project and an overall Program Grade will provide management with a beneficial decision support tool when planning future programs. It would also reduce a lot of the rework that currently goes into program process guides and developing strategies for the various cutter classes and their particular needs.

Given the importance of implementing organizational efficiency improvements, particularly the ones stated in the literature, a priority list has been developed in Table 5.2.4. While in communication with the management of the CG Yard, they were interested in finding solutions to two major business obstacles. First, they wanted an analysis of the Critical Chain Project Management process used at the CG Yard with a recommendation of how to optimize project management based on the tools and resources that they currently possess. Secondly, they wanted an analysis of their scheduling processes and how to incorporate an Integrated Master Plan (B.L. Melvin, personal communication-email/phone conversation March 31, 2014). With these goals in mind, and understanding that the organization sees a need and is willing to introduce new management techniques and tools, the list below states the most critical steps for improved project management with the lowest cost (labor, tools, and time).

| Priority | Business Improvements | Feasibility For Implementation |
|---|---|---|
| 1 | Create Integrated Master Schedule | High-Requires human capital to develop |
| 2 | Implement Risk Management in Estimating Task Duration | High-Need historical data or MC Simulation |
| 3 | Verify Program Policies/Procedures with Past Data (If Available) | Medium-Requires Data & Data Analysis |
| 4 | Create Program Grading Rubric | Medium-Requires Data & Data Analysis |
| 5 | Acquire New Software for Simulation Modeling & Schedule Optimization | Low-Large Capital Investment Required Plus Support Services |

**Table 5.2.4 Prioritized Organizational Efficiency Improvements based upon Feasibility for Implementation at the CG Yard.**

# CHAPTER 6

# GENERAL CONCLUSIONS

## 6.1 Overall Findings

Through the use of spreadsheet models, the 87' Bow to Stern Program's resource loading with three concurrent projects and a level-loading analysis of job shop X-11 were achieved. The results of this analysis shows that given available resources (time, infrastructure, tools, people, etc.), the loading of each availability will be to capacity, particularly within the paint shop, and will cause or create worry for delay if not mitigated appropriately. For one availability, the 25.1 (22.2) person work crew is not ideal because the shifts are not being filled and the number of people working in the small space is too high, therefore resources are wasted. Splitting the crew in half (or some variation to meet the job shop work schedule for each cutter) lowers the people per workspace, but also increases the majority of the availability's workload to two shifts per day. By adding the third cutter, the original crew is spread very thin in trying to complete consecutive work on three cutters. If not managed appropriately, this could result in movement waste as workers move from cutter to cutter.

The level-loading analysis of job shop X-11 results in moderate man-hour loads over small ranges of time within the project timeline. This allows for better planning of resources on a weekly basis as opposed to daily resource adjustment, lower probabilities of needing overtime and overmanning, and more routine work shifts for the workers. The planning labor required to level-load all job shops by hand while keeping the integrity of work sequencing is extremely difficult if not impossible to optimize. By implementing an Integrated Master Plan (IMP) into the software capabilities of Oracle Primavera, shared resources can be loaded across all concurrent projects throughout the shipyard. Any movement of resources in order to speed up higher priority projects will result in adjustments to other projects and the use of other forms of mitigation strategies.

If mitigation strategies need to be implemented beyond what an IMP can account for, then the CG Yard needs to better understand how their workforce behaves, particularly at what point in time fatigue from overtime negatively affects work quality. By conducting work studies in an iterative fashion, the CG Yard will have better decision control over which responsive actions to take when schedule risk occurs. Similarly, by adopting newer, preemptive strategies that improve process cycle times, bolster worker skills, and eliminate common wastes, the organization will be more flexible to changes in project schedule or resources.

## 6.2 Future Research

Due to the fact that the majority of the data for the completed and future projects are not yet available, there are several opportunities in the future to analyze all 87’ Bow to Stern Program cutter data. The descriptive statistics (mean, standard deviation, etc.) of actual man-hours required to complete each project (broken down by subtask and job shop) given the parallel work schedule, can be stored as historical estimating data for the CG Yard. This data can also be compared against previous estimating methods to see how accurate the estimates really were and then provide a benchmark for future programs. The method for organizing tasks presented in this paper can be validated against the final iteration of the WBS and Gantt Chart to determine if the assumptions made and procedures followed are sound. Risk management techniques in estimating for CPM, like Monte Carlo Simulation, could be applied to determine how it impacts the critical path. The CG Yard also needs to assess its current scheduling software to ensure it is adequate enough to support concurrent projects. A cost benefit analysis should be conducted for a proposal for adding features to current scheduling software and to develop an Integrated Master Plan. Once created, an evaluation of past (without IMP) versus future project (with IMP) performance should be made. Furthermore, the cost to develop optimization software or an algorithm for level-loading projects to be used within existing scheduling software should be considered. This would reduce the need to relearn new software and just add additional capabilities for schedule analysis. Simulation modeling could be used in several areas of the CG Yard to verify schedule risk mitigation strategies on overall production improvements. The current and proposed scenarios for a single job shop, perhaps the paint shop, could be modeled to see how adding a new tool or process (like Jobshop Lean or multiskilling) could reduce the number of man-hours required for the availability prior to physical implementation.

## 6.3 Contributions

The analysis of the Coast Guard’s 87’ Bow to Stern Program using spreadsheet modeling, presented an inexpensive, fairly straightforward, and valuable tool to make a detailed analysis of raw data when dealing with limited software capabilities. The results of the analysis, and the subsequent recommendations, highlight the many challenges government-run shipyards face today. The limited number of competitive naval shipyards, highly skilled workforces, and capital to invest in new technologies to improve project management put a strain on project managers to derive solutions within their means. Furthermore, project managers have the onus to take on large organizational improvements on top of their regular duties in order to make helpful changes. Such challenges when faced with a unionized workforce, a military hierarchy, and short tour lengths require exceptional leadership skills. Customers and workers alike have buy-in for better work practices, but they need to be confident in the goals and methods of the management team. The current planning tools at the CG Yard are not capable of providing that level of confidence without implementation of an Integrated Master Plan and more robust estimating methods.

This project also highlights the need for more industry-specific overtime studies that focus more on application and less on theory. In order to avoid overages on budget and schedule, strategies for compressing task times need to be analyzed to ensure their impact on the feedback loop is balancing and not reinforcing. Methods for analyzing worker fatigue, the calculations needed to determine worker efficiency, and the impacts of learning, forgetting, and preemption all impact the overall capabilities of the workforce. By understanding how workers behave in a specific industry, project managers can make well thought out decisions in the face of project crises.

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# APPENDIX

## ANNOTATED TABLES AND GRAPHS INCLUDING PLANNING DATA AND RESULTS

| East Coast | West Coast |
|---|---|
| ALBACORE (WPB 87309) Little Creek, VA | ADELIE (WPB 87333) Port Angeles, WA |
| ALLIGATOR (WPB 87372) St. Petersburg, FL | AHI (WPB 87364) Honolulu, HI |
| AMBERJACK (WPB 87315) Port Isabel, TX | BARRACUDA (WPB 87301) Eureka, CA |
| BELUGA (WPB 87325) Little Creek, VA | BLACKFIN (WPB 87317) Santa Barbara, CA |
| BLUEFIN (WPB 87318) Fort Pierce, FL | BLACKTIP (WPB 87326) Oxnard, CA |
| BONITO (WPB 87341) Pensacola, FL | BLUE SHARK (WPB 87360) Everett, WA |
| BRANT (WPB 87348) Corpus Christi, TX | DORADO WPB 87306) Crescent City, CA |
| CHINOOK (WPB 87308) New London, CT | HADDOCK (WPB 87347) San Diego, CA |
| COBIA (WPB 87311) Mobile, AL | HALIBUT (WPB 87340) Marina Del Rey, CA |
| COCHITO (WPB 87329) Little Creek, VA | HAWKSBILL (WPB 87312) Monterey, CA |
| COHO (WPB 87321) Panama City, FL | KITTIWAKE (WPB 87316) Honolulu, HI |
| CORMORANT (WPB 87313) Fort Pierce, FL | NARWHAL (WPB 87335) Corona Del Mar, CA |
| CROCODILE (WPB 87369) St Petersburg, FL | OSPREY (WPB 87307) Port Townsend, WA |
| DIAMONDBACK (WPB 87370) Miami Beach, FL | PETREL (WPB 87350) San Diego, CA |
| DOLPHIN (WPB 87354) Miami, FL | PIKE (87365) San Francisco, CA |
| FINBACK (WPB 87314) Cape May, NJ | SEA DEVIL (WPB 87368) Bangor, WA |
| FLYINGFISH (WPB 87346) Boston, MA | SEA FOX (WPB 87374) Bangor, WA |
| GANNET (WPB 87334) Dania, FL | SEA LION (WPB 87352) Bellingham, WA |
| HAMMERHEAD (WPB 87302) Woods Hole, MA | SEA OTTER (WPB 87362) San Diego, CA |
| HAWK (WPB 87355) St. Petersburg, FL | SWORDFISH (WPB 87358) Port Angeles, WA |
| HERON (WPB 87344) Sabine, TX | SOCKEYE (WPB 87337) Bodega Bay, CA |
| IBIS (WPB 87338) Cape May, NJ | TERN (WPB 87343) San Francisco, CA |
| KINGFISHER (WPB 87322) Mayport, FL | TERRAPIN (WPB 87366) Bellingham, WA |
| MAKO (WPB 87303) Cape May, NJ | WAHOO (WPB 87345) Port Angeles, WA |
| MANATEE (WPB 87363) Corpus Christi, TX | |
| MANOWAR (WPB 87330) Galveston, TX | |
| MANTA (WPB 87320) Freeport, TX | 49 East Coast Cutters |
| MARLIN (WPB 87304) Fort Myers Beach, FL | 24 West Coast Cutters |
| MORAY (WPB 87331) Jonesport, ME | |
| PELICAN (WPB 87327) Abbeveille, LA | |
| POMPANO (WPB 87339) Gulfport, MS | |
| RAZORBILL (WPB 87332) Gulfport, MS | |
| REEF SHARK (WPB 87371) San Juan, PR | |
| RIDLEY (WPB 87328) Montauk, NY | |
| SAILFISH (WPB 87356) Sandy Hook, NJ | |
| SAWFISH (WPB 87357) Key West, FL | |
| SEA DOG (WPB 87373) Kings Bay, GA | |
| SEA DRAGON (WPB 87367) Kings Bay, GA | |
| SEA HORSE (WPB 87361) Portsmouth, VA | |
| SEAHAWK (WPB 87323) Carrabelle, FL | |
| SHEARWATER (WPB 87349) Portsmouth, VA | |
| SHRIKE (WPB 87342) Port Canaveral, FL | |
| SKIPJACK (WPB 87353) Galveston, TX | |
| STEELHEAD (WPB 87324) Port Aransas, TX | |
| STINGRAY (WPB 87305) Mobile, AL | |
| STURGEON (WPB 87336) Grand Isle, LA | |
| TARPON (WPB 87310) Tybee Island, GA | |
| TIGER SHARK (WPB 87359) Newport, RI | |
| YELLOWFIN (WPB 87319) Charleston, SC | |

**Table A.1 List of all East and West Coast 87' Coastal Patrol Boats by name, cutter number, and homeport.**

| Work Item # | Description | Job Shop | Man-Hours | Date to Complete | Updated WBS Sequencing |
|---|---|---|---|---|---|
| wi 10 | preparation | x11 | 4. | 12/31-1/2 | 5-J |
| wi 10 | alignment | x11 | 4.00 | 12/31-1/2 | 5-Jan |
| wi 15 | preparation | x11 | 12.00 | 11/14-11/22 | 11/14-11/21 |
| wi 16 | protective meas. | x11 | 2.00 | 11/6-11/12 | 7-Nov |
| wi 16 | remove (propeller) | x11 | 2.00 | 11/6-11/12 | 11/7-11/13 |
| wi 2 | ut shots | x11 | 8.00 | 1-Dec | 11/23-12/2 |
| wi 20 | visual inspection | x11 | 2.00 | 4-Nov | 11/5-11/6 |
| wi 20 | remove (stern launch door) | x11 | 10.00 | 11/6-11/12 | 11/7-11/13 |
| wi 20 | install (bracing) | x11 | 4.00 | 11/6-11/12 | 11/7-11/13 |
| wi 20 | install (stern launch door) | x11 | 10.00 | 18-Dec | 12/12-12/26 |
| wi 21 | open tanks | x11 | 2.00 | 5-Nov | 11/5-11/6 |
| wi 21 | inspect tanks | x11 | 4.00 | 12-Nov | 13-Nov |
| wi 21 | final inspect | x11 | 8.00 | 12/11-12/16 | 12/12-12/26 |
| wi 21 | close tanks | x11 | 4.00 | 12/11-12/16 | 12/12-12/26 |
| wi 22 | open tanks | x11 | 2.00 | 5-Nov | 11/5-11/6 |
| wi 22 | inspect tanks | x11 | 4.00 | 12-Nov | 13-Nov |
| wi 22 | final inspect | x11 | 8.00 | 12/11-12/16 | 12/12-12/26 |
| wi 22 | close tanks | x11 | 2.00 | 12/11-12/16 | 12/12-12/26 |
| wi 25 | preps/removals | x11 | 10.00 | 13-Nov | 11/7-11/13 |
| wi 25 | reinstalls | x11 | 10.00 | 12/11-12/16 | 12/12-12/26 |
| wi 26 | preparation | x11 | 14.00 | 13-Nov | 11/7-11/13 |
| wi 26 | reinstalls | x11 | 10.00 | 12/11-12/29 | 12/12-12/26 |
| wi 27 | preps/removals | x11 | 16.00 | 11/6-11/12 | 4-5NOV |
| wi 27 | reinstalls | x11 | 19.00 | 12/17-12/29 | 12/12-12/26 |
| wi 28 | preps/removals | x11 | 14.00 | 11/6-11/13 | 11/7-11/13 |
| wi 28 | reinstalls | x11 | 16.00 | 12/11-12/29 | 12/12-12/26 |
| wi 29 | renew zinc anodes | x11 | 34.00 | 12/11-12/16 | 12/12-12/18 |
| wi 30 | dry dock vsl | x11 | 18.00 | 6-Nov | 7-Nov |
| wi 30 | undock vsl | x11 | 9.00 | 30-Dec | 2-Jan |
| wi 33 | crop/renew | x11 | 45.00 | 11/23-12/2 | 11/23-12/2 |
| wi 34 | preps/removals | x11 | 10.00 | 13-Nov | 11/7-11/13 |
| wi 34 | reinstalls | x11 | 6.00 | 12/11-12/16 | 12/12-12/26 |
| wi 36 | protective meas. | x11 | 2.00 | 11/6-11/12 | 11/7-11/13 |
| wi 36 | interferences | x11 | 4.00 | 11/6-11/12 | 11/7-11/13 |
| wi 36 | major misalignment | x11 | 8.00 | 11/13-12/2 | 11/17-11/18 |
| wi 36 | remove (shafts) | x11 | 7.00 | 11/6-11/12 | 11/7-11/13 |
| wi 36 | inspections | x11 | 4.00 | 11/6-11/12 | 11/7-11/23 |
| wi 3a | open tanks | x11 | 18.00 | 5-Nov | 11/5-11/6 |
| wi 3a | final inspect | x11 | 2.00 | 12/11-12/16 | 12/19-12/26 |
| wi 3a | close tanks | x11 | 18.00 | 12/11-12/16 | 12/19-12/26 |
| wi 3b | remove (framing) | x11 | 10.00 | 11/24-12/2 | 11/7-11/23 |
| wi 3b | cut access holes | x11 | 20.00 | 11/24-12/2 | 11/7-11/23 |
| wi 3b | install (framing) | x11 | 10.00 | 12/11-12/16 | 12/19-12/26 |
| wi 3b | reinstalls | x11 | 16.00 | 12/11-12/16 | 12/19-12/26 |
| wi 4a | open tanks | x11 | 18.00 | 5-Nov | 11/5-11/6 |
| wi 4a | final inspect | x11 | 2.00 | 12/11-12/16 | 12/19-12/26 |
| wi 4a | close tanks | x11 | 18.00 | 12/11-12/16 | 12/19-12/26 |
| wi 4b | reinstalls | x11 | 8.00 | 12/11-12/16 | 12/19-12/26 |
| wi 4b | preps/removals | x11 | 8.00 | 11/24-12/2 | 11/7-11/23 |
| wi 5 | open tanks | x11 | 2.00 | 5-Nov | 11/5-11/6 |
| wi 5 | inspect tanks | x11 | 2.00 | 12-Nov | 11/7-11/13 |
| wi 5 | final inspect | x11 | 6.00 | 12/11-12/16 | 12/12-12/26 |
| wi 5 | close tanks | x11 | 2.00 | 12/11-12/16 | 12/12-12/26 |
| wi 6 | final inspect | x11 | 6.00 | 12/11-12/16 | 12/12-12/26 |
| wi 6 | close tanks | x11 | 2.00 | 12/11-12/16 | 12/12-12/26 |
| wi 6 | open tanks | x11 | 2.00 | 5-Nov | 11/5-11/6 |
| wi 6 | inspect tanks | x11 | 2.00 | 12-Nov | 11/7-11/13 |
| wi 7 | open tanks | x11 | 4.00 | 5-Nov | 11/5-11/6 |
| wi 7 | inspect tanks | x11 | 8.00 | 12-Nov | 11/7-11/13 |
| wi 7 | final inspect | x11 | 10.00 | 12/11-12/16 | 12/12-12/26 |
| wi 7 | close tanks | x11 | 4.00 | 12/11-12/16 | 12/12-12/26 |
| wi 8 | open tanks | x11 | 4.00 | 5-Nov | 11/5-11/6 |
| wi 8 | inspect tanks | x11 | 6.00 | 12-Nov | 11/7-11/13 |
| wi 8 | final inspect | x11 | 4.00 | 12/11-12/16 | 12/12-12/26 |
| wi 8 | close tanks | x11 | 2.00 | 12/11-12/16 | 12/12-12/26 |
| wi 9 | preps/removals | x11 | 4.00 | 11/6-11/12 | 11/7-11/13 |
| | | Total Hours | 566.00 | | |

**Table A.2 Job Shop X-11 Original and Level-Loaded Subtask Breakdown with man-hours and scheduled completion dates.**

Availability Start Date | Weekends/Holidays

| X-11 | 4-Nov | 5-Nov | 6-Nov | 7-Nov | 8-Nov | 9-Nov | 10-Nov | 11-Nov | 12-Nov | 13-Nov | 14-Nov | 15-Nov | 16-Nov | 17-Nov | 18-Nov | 19-Nov | 20-Nov | 21-Nov | 22-Nov | 23-Nov | 24-Nov | 25-Nov | 26-Nov | 27-Nov | 28-Nov |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IBIS | 2 | 52 | 34.6 | 16.6 | | | 16.6 | | 42.6 | 36.8 | 2 | | | 4 | 4 | 4 | 4 | 2 | | | 13.8 | 13.8 | 13.8 | | 13.8 |
| STINGRAY | | | | | | | | | | | | | | | | | | | | | | | | | |
| HAMMERHEAD | | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL MHs | 2 | 52 | 34.6 | 16.6 | 0 | 0 | 16.6 | 0 | 42.6 | 36.8 | 2 | 0 | 0 | 4 | 4 | 4 | 4 | 2 | 0 | 0 | 13.8 | 13.8 | 13.8 | 0 | 13.8 |

| X-11 | 29-Nov | 30-Nov | 1-Dec | 2-Dec | 3-Dec | 4-Dec | 5-Dec | 6-Dec | 7-Dec | 8-Dec | 9-Dec | 10-Dec | 11-Dec | 12-Dec | 13-Dec | 14-Dec | 15-Dec | 16-Dec | 17-Dec | 18-Dec | 19-Dec | 20-Dec | 21-Dec | 22-Dec | 23-Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IBIS | | | 21.8 | 13.8 | | | | | | | | | 47.7 | 47.7 | | | 47.7 | 47.7 | 4.6 | 14.6 | 4.6 | | | 4.6 | 4.6 |
| STINGRAY | | | 2 | 52 | 34.6 | 16.6 | 16.6 | | | | 42.6 | 36.8 | 2 | 4 | | | 4 | 4 | 4 | | 2 | | | 13.8 | 13.8 |
| HAMMERHEAD | | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL MHs | 0 | 0 | 23.8 | 65.8 | 34.6 | 16.6 | 16.6 | 0 | 0 | 0 | 42.6 | 36.8 | 49.7 | 51.7 | 0 | 0 | 51.7 | 51.7 | 8.6 | 14.6 | 6.6 | 0 | 0 | 18.4 | 18.4 |

| X-11 | 24-Dec | 25-Dec | 26-Dec | 27-Dec | 28-Dec | 29-Dec | 30-Dec | 31-Dec | 1-Jan | 2-Jan | 3-Jan | 4-Jan | 5-Jan | 6-Jan | 7-Jan | 8-Jan | 9-Jan | 10-Jan | 11-Jan | 12-Jan | 13-Jan | 14-Jan | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IBIS | 4.6 | | 4.6 | | | 4.6 | 9 | 4 | | 4 | | | | | | | | | | | | | | | |
| STINGRAY | 13.8 | | 13.8 | | | 21.8 | 13.8 | | | | | | | | 47.7 | 47.7 | 47.7 | | | 47.7 | 4.6 | 14.6 | | | |
| HAMMERHEAD | | | | | | | | | | | | | 2 | 52 | 34.6 | 16.6 | 16.6 | | | | 42.6 | 36.8 | | | |
| TOTAL MHs | 18.4 | 0 | 18.4 | 0 | 0 | 26.4 | 22.8 | 4 | 0 | 4 | 0 | 0 | 2 | 52 | 82.3 | 64.3 | 64.3 | 0 | 0 | 47.7 | 47.2 | 51.4 | | | |

**Figure A.1 Calendar Schedule Representation of Job Shop X-11 Loading over Three Parallel Availabilities.**

| Work Item # | Description | Job Shop | Man-Hours | Date to Complete |
|---|---|---|---|---|
| wi 20 | remove (stern launch door) | x12 | 4.00 | 11/6-11/12 |
| wi 20 | install (bracing) | x12 | 4.00 | 6-Nov |
| wi 21 | open tanks | x12 | 6.00 | 5-Nov |
| wi 21 | final inspect | x12 | 6.00 | 15-Dec |
| | | Total Hours | 20.00 | |

**Table A.3 Job Shop X-12 Subtask Breakdown with man-hours and scheduled completion dates.**

Availability Start Date | Weekends/Holidays

| X-12 | 4-Nov | 5-Nov | 6-Nov | 7-Nov | 8-Nov | 9-Nov | 10-Nov | 11-Nov | 12-Nov | 13-Nov | 14-Nov | 15-Nov | 16-Nov | 17-Nov | 18-Nov | 19-Nov | 20-Nov | 21-Nov | 22-Nov | 23-Nov | 24-Nov | 25-Nov | 26-Nov | 27-Nov | 28-Nov |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IBIS | | 6 | 4 | 4 | | | | | | | | | | | | | | | | | | | | | |
| STINGRAY | | | | | | | | | | | | | | | | | | | | | | | | | |
| HAMMERHEAD | | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL MHs | 0 | 6 | 4 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| X-12 | 29-Nov | 30-Nov | 1-Dec | 2-Dec | 3-Dec | 4-Dec | 5-Dec | 6-Dec | 7-Dec | 8-Dec | 9-Dec | 10-Dec | 11-Dec | 12-Dec | 13-Dec | 14-Dec | 15-Dec | 16-Dec | 17-Dec | 18-Dec | 19-Dec | 20-Dec | 21-Dec | 22-Dec | 23-Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IBIS | | | | | | | | | | | | | | | | | 6 | | | | | | | | |
| STINGRAY | | | | 6 | 4 | 4 | | | | | | | | | | | | | | | | | | | |
| HAMMERHEAD | | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL MHs | 0 | 0 | 0 | 6 | 4 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| X-12 | 24-Dec | 25-Dec | 26-Dec | 27-Dec | 28-Dec | 29-Dec | 30-Dec | 31-Dec | 1-Jan | 2-Jan | 3-Jan | 4-Jan | 5-Jan | 6-Jan | 7-Jan | 8-Jan | 9-Jan | 10-Jan | 11-Jan | 12-Jan | 13-Jan | 14-Jan | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IBIS | | | | | | | | | | | | | | | | | | | | | | | | | |
| STINGRAY | | | | | | | | | | | | | | | | | | | | | | | | | |
| HAMMERHEAD | | | | | | | | | | | | | | 6 | 4 | 4 | | | | | | | | | |
| TOTAL MHs | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 4 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Figure A.2 Calendar Schedule Representation of Job Shop X-12 Loading over Three Parallel Availabilities.**

| Work Item # | Description | Job Shop | Man-Hours | Date to Complete |
|---|---|---|---|---|
| wi 10 | preparation | x13 | 4.00 | 12/31-1/2 |
| wi 10 | alignment | x13 | 4.00 | 12/31-1/2 |
| wi 18 | inspect | x13 | 6.00 | 4-Nov |
| wi 20 | install (stern launch door) | x13 | 4.00 | 18-Dec |
| wi 20 | install (bracing) | x13 | 4.00 | 11/6-11/12 |
| wi 27 | preps/removals | x13 | 28.00 | 11/6-11/12 |
| wi 27 | reinstalls | x13 | 16.00 | 12/17-12/29 |
| wi 29 | renew zinc anodes | x13 | 4.00 | 12/11-12/16 |
| wi 30 | dry dock vsl | x13 | 2.00 | 6-Nov |
| wi 30 | undock vsl | x13 | 2.00 | 30-Dec |
| wi 31 | connect temp services | x13 | 6.00 | 6-Nov |
| wi 31 | final removals | x13 | 2.00 | 13-Jan |
| wi 33 | crop/renew | x13 | 60.00 | 11/23-12/2 |
| wi 36 | install (shaft asmb) | x13 | 6.00 | 12/17-12/29 |
| wi 36 | protective meas. | x13 | 2.00 | 5-Nov |
| wi 36 | interferences | x13 | 1.00 | 5-Nov |
| wi 36 | major misalignment | x13 | 4.00 | 11/13-12/2 |
| wi 36 | remove (shafts) | x13 | 8.00 | 11/6-11/12 |
| wi 3b | reinstalls | x13 | 16.00 | 12/11-12/16 |
| | | Total Hours | 179.00 | |

**Table A.4 Job Shop X-13 Subtask Breakdown with man-hours and scheduled completion dates.**

Availability Start Date | Weekends/Holidays

| X-13 | 4-Nov | 5-Nov | 6-Nov | 7-Nov | 8-Nov | 9-Nov | 10-Nov | 11-Nov | 12-Nov | 13-Nov | 14-Nov | 15-Nov | 16-Nov | 17-Nov | 18-Nov | 19-Nov | 20-Nov | 21-Nov | 22-Nov | 23-Nov | 24-Nov | 25-Nov | 26-Nov | 27-Nov | 28-Nov |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IBIS | 6 | 3 | 18 | 10 | | | 10 | | 10 | 4 | | | | | | | | | | | 10 | 10 | 10 | | 10 |
| STINGRAY | | | | | | | | | | | | | | | | | | | | | | | | | |
| HAMMERHEAD | | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL MHs | 6 | 3 | 18 | 10 | 0 | 0 | 10 | 0 | 10 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 10 | 10 | 0 | 10 |

| X-13 | 29-Nov | 30-Nov | 1-Dec | 2-Dec | 3-Dec | 4-Dec | 5-Dec | 6-Dec | 7-Dec | 8-Dec | 9-Dec | 10-Dec | 11-Dec | 12-Dec | 13-Dec | 14-Dec | 15-Dec | 16-Dec | 17-Dec | 18-Dec | 19-Dec | 20-Dec | 21-Dec | 22-Dec | 23-Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IBIS | | | 10 | 10 | | | | | | | | | 5 | 5 | | | 5 | 5 | 2.8 | 2.8 | 2.8 | | | 2.8 | 2.8 |
| STINGRAY | | | 6 | 3 | 18 | 10 | | | 10 | | 10 | 4 | | | | | | | | | | | 10 | 10 | 10 |
| HAMMERHEAD | | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL MHs | 0 | 0 | 16 | 13 | 18 | 10 | 0 | 0 | 10 | 0 | 10 | 4 | 5 | 5 | 0 | 0 | 5 | 5 | 2.8 | 2.8 | 2.8 | 0 | 10 | 13 | 13 |

| X-13 | 24-Dec | 25-Dec | 26-Dec | 27-Dec | 28-Dec | 29-Dec | 30-Dec | 31-Dec | 1-Jan | 2-Jan | 3-Jan | 4-Jan | 5-Jan | 6-Jan | 7-Jan | 8-Jan | 9-Jan | 10-Jan | 11-Jan | 12-Jan | 13-Jan | 14-Jan | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IBIS | 2.8 | | 2.8 | | | 2.8 | 2 | 4 | | 4 | | | | | | | | | | | 2 | | | | |
| STINGRAY | 10 | | 10 | 0 | | 10 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 5 | 0 | 0 | 5 | 5 | 2.8 | 6.8 | | | |
| HAMMERHEAD | | | | | | | | | | | | | 6 | 3 | 18 | 10 | | | 10 | | 10 | 4 | | | |
| TOTAL MHs | 13 | 0 | 13 | 0 | 0 | 13 | 12 | 4 | 0 | 4 | 0 | 0 | 6 | 3 | 23 | 15 | 0 | 0 | 15 | 5 | 15 | 11 | | | |

**Figure A.3 Calendar Schedule Representation of Job Shop X-13 Loading over Three Parallel Availabilities.**

| Work Item # | Description | Job Shop | Man-Hours | Date to Complete |
|---|---|---|---|---|
| wi 10 | preparation | x14 | 8.00 | 12/31-1/2 |
| wi 10 | alignment | x14 | 8.00 | 12/31-1/2 |
| wi 16 | remove (propeller) | x14 | 2.00 | 11/6-11/12 |
| wi 20 | install (bracing) | x14 | 8.00 | 6-Nov |
| wi 20 | install (stern launch | x14 | 8.00 | 18-Dec |
| wi 27 | preps/removals | x14 | 14.00 | 11/6-11/12 |
| wi 27 | reinstalls | x14 | 14.00 | 1/9-1/13 |
| wi 33 | crop/renew | x14 | 60.00 | 11/14-11/22 |
| wi 36 | install (shaft asmb) | x14 | 12.00 | 12/17-12/29 |
| wi 36 | interferences | x14 | 2.00 | PRIOR TO 11/6 |
| wi 36 | remove (shafts) | x14 | 18.00 | 11/6-11/12 |
| wi 3b | cut access holes | x14 | 24.00 | 11/23-12/2 |
| wi 3b | reinstalls | x14 | 42.00 | 12/11-12/16 |
| | | Total Hours | 220.00 | |

**Table A.5 Job Shop X-14 Subtask Breakdown with man-hours and scheduled completion dates.**

| | Availability Start Date | Weekends/Holidays |
|---|---|---|

| X-14 | 4-Nov | 5-Nov | 6-Nov | 7-Nov | 8-Nov | 9-Nov | 10-Nov | 11-Nov | 12-Nov | 13-Nov | 14-Nov | 15-Nov | 16-Nov | 17-Nov | 18-Nov | 19-Nov | 20-Nov | 21-Nov | 22-Nov | 23-Nov | 24-Nov | 25-Nov | 26-Nov | 27-Nov | 28-Nov |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IBIS | 2 | 10.5 | 10.5 | | | 10.5 | | 10.5 | | 10 | | | 10 | 10 | 10 | 10 | 10 | | | 4 | 4 | 4 | | 4 | 14 |
| STINGRAY | | | | | | | | | | | | | | | | | | | | | | | | | |
| HAMMERHEAD | | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL MHs | 2 | 10.5 | 10.5 | 0 | 0 | 10.5 | 0 | 10.5 | 0 | 10 | 0 | 0 | 10 | 10 | 10 | 10 | 10 | 0 | 0 | 4 | 4 | 4 | 0 | 4 | 14 |

| X-14 | 29-Nov | 30-Nov | 1-Dec | 2-Dec | 3-Dec | 4-Dec | 5-Dec | 6-Dec | 7-Dec | 8-Dec | 9-Dec | 10-Dec | 11-Dec | 12-Dec | 13-Dec | 14-Dec | 15-Dec | 16-Dec | 17-Dec | 18-Dec | 19-Dec | 20-Dec | 21-Dec | 22-Dec | 23-Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IBIS | | | 4 | 4 | | | | | | | | | 10.5 | 10.5 | | | 10.5 | 11 | 1.7 | 8 | 2 | | | 1.7 | 1.7 |
| STINGRAY | | | 2 | 10.5 | 10.5 | | | 10.5 | | 10.5 | | 10 | | | 10 | 10 | 10 | 10 | 10 | | | 4 | 4 | 4 | |
| HAMMERHEAD | | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL MHs | 0 | 0 | 6 | 14.5 | 10.5 | 0 | 0 | 10.5 | 0 | 10.5 | 0 | 10 | 10.5 | 10.5 | 10 | 10 | 20.5 | 21 | 12 | 8 | 2 | 4 | 4 | 5.7 | 1.7 |

| X-14 | 24-Dec | 25-Dec | 26-Dec | 27-Dec | 28-Dec | 29-Dec | 30-Dec | 31-Dec | 1-Jan | 2-Jan | 3-Jan | 4-Jan | 5-Jan | 6-Jan | 7-Jan | 8-Jan | 9-Jan | 10-Jan | 11-Jan | 12-Jan | 13-Jan | 14-Jan | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IBIS | 1.7 | | 1.7 | | | 1.7 | | 8 | | 8 | | | | | | | 4.67 | | | 4.7 | 5 | | | | |
| STINGRAY | 4 | | 4 | | | 4 | | | | | | | | 10.5 | 10.5 | 10.5 | 10.5 | | | 1.7 | 8 | 1.7 | | | |
| HAMMERHEAD | | | | | | | | | | | | | 2 | 10.5 | 10.5 | | | 11 | | 11 | | 10 | | | |
| TOTAL MHs | 5.7 | 0 | 5.7 | 0 | 0 | 5.7 | 0 | 8 | 0 | 8 | 0 | 0 | 2 | 21 | 21 | 10.5 | 15.17 | 11 | 0 | 17 | 13 | 11.7 | | | |

**Figure A.4 Calendar Schedule Representation of Job Shop X-14 Loading over Three Parallel Availabilities.**

| Work Item # | Description | Job Shop | Man-Hours | Date to Complete |
|---|---|---|---|---|
| support service per day | | x21 | | |
| support services | | x21 | 45.00 | 0.9375 |
| wi 10 | preparation | x21 | 4.00 | 12/31-1/2 |
| wi 10 | alignment | x21 | 4.00 | 12/31-1/2 |
| wi 17 | remove (exhaust lagging) | x21 | 24.00 | 12/1-12/16 |
| wi 17 | install/test | x21 | 32.00 | 12/17-12/29 |
| wi 18 | remove (valve/strainer) | x21 | 40.00 | 11/6-11/12 |
| wi 18 | clean/inspect | x21 | 36.00 | 11/13-12/1 |
| wi 18 | install (valve/strainers) | x21 | 40.00 | 12/1-12/16 |
| wi 18 | op test | x21 | 27.00 | 12/17-12/29 |
| wi 18 | inspect | x21 | 27.00 | 11/13-12/1 |
| wi 20 | interferences | x21 | 6.00 | 11/6-11/12 |
| wi 20 | op test | x21 | 2.00 | 11/4 and 12/22 |
| wi 20 | visual inspection | x21 | 1.00 | 4-Nov |
| wi 20 | install (stern launch door) | x21 | 9.00 | 18-Dec |
| wi 21 | inspect tanks | x21 | 6.00 | 12-Nov |
| wi 21 | final inspect | x21 | 6.00 | 12/11-12/16 |
| wi 22 | inspect tanks | x21 | 10.00 | 12-Nov |
| wi 22 | final inspect | x21 | 6.00 | 12/11-12/16 |
| wi 23 | install (spool) | x21 | 12.00 | 12/11-12/16 |
| wi 23 | inspect | x21 | 6.00 | 12/17-12/29 |
| wi 23 | install (tank valves) | x21 | 10.00 | 12/11-12/29 |
| wi 23 | op test | x21 | 10.00 | 11/13 and 12/17-29 |
| wi 24 | install (spool) | x21 | 10.00 | 12/11-12/16 |
| wi 24 | inspect | x21 | 6.00 | 12/17-12/29 |
| wi 24 | install (tank valves) | x21 | 6.00 | 12/11-12/16 |
| wi 24 | op test | x21 | 8.00 | 11/13 and 12/17-29 |
| wi 25 | preps/removals | x21 | 4.00 | 11/6-11/13 |
| wi 26 | preparation | x21 | 20.00 | 11/6-11/13 |
| wi 26 | reinstalls | x21 | 20.00 | 12/11-12/16 |
| wi 28 | preps/removals | x21 | 6.00 | 11/6-11/13 |
| wi 28 | reinstalls | x21 | 6.00 | 12/11-12/16 |
| wi 30 | dry dock vsl | x21 | 12.00 | 6-Nov |
| wi 30 | undock vsl | x21 | 12.00 | 30-Dec |
| wi 31 | connect temp services | x21 | 9.00 | 11/6-11/12 |
| wi 31 | final removals | x21 | 9.00 | 13-Jan |
| wi 32 | sea trials | x21 | 48.00 | 1/9-1/13 |
| wi 32 | ride in | x21 | 8.00 | 4-Nov |
| wi 33 | crop/renew | x21 | 60.00 | 11/23-12/2 |
| wi 34 | preps/removals | x21 | 2.00 | 11/6-11/13 |
| wi 34 | reinstalls | x21 | 2.00 | 12/11-12/16 |
| wi 35 | remove (shaft seal) | x21 | 18.00 | 11/6-11/12 |
| wi 35 | install/test/preserve | x21 | 32.00 | 12/17-12/29 |
| wi 36 | remove (shafts) | x21 | 2.00 | 11/6-11/12 |
| wi 37 | water hose test | x21 | 2.00 | 12/17-12/29 |
| wi 3b | remove (steering) | x21 | 10.00 | 11/23-12/2 |
| wi 3b | remove (bilge) | x21 | 4.00 | 11/23-12/2 |
| wi 3b | remove (l/o) | x21 | 14.00 | 11/23-12/2 |
| wi 3b | install (steering) | x21 | 10.00 | 12/11-12/16 |
| wi 3b | install (bilge) | x21 | 4.00 | 12/11-12/16 |
| wi 3b | install (l/o) | x21 | 14.00 | 12/11-12/16 |
| wi 4b | reinstalls | x21 | 32.00 | 12/11-12/16 |
| wi 4b | preps/removals | x21 | 24.00 | 11/23-12/2 |
| wi 5 | inspect tanks | x21 | 3.00 | 12-Nov |
| wi 5 | final inspect | x21 | 2.00 | 12/11-12/16 |
| wi 6 | final inspect | x21 | 2.00 | 12/11-12/16 |
| wi 6 | inspect tanks | x21 | 3.00 | 12-Nov |
| wi 7 | inspect tanks | x21 | 6.00 | 12-Nov |
| wi 7 | final inspect | x21 | 2.00 | 12/11-12/16 |
| wi 8 | inspect tanks | x21 | 4.00 | 12-Nov |
| wi 8 | final inspect | x21 | 2.00 | 12/11-12/16 |
| wi 8 | close tanks | x21 | 15.00 | 12/11-12/16 |
| | | Total Hours | 816.00 | |

**Table A.6 Job Shop X-21 Subtask Breakdown with man-hours and scheduled completion dates.**

| | Availability Start Date | | | | | | Weekends/Holidays | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| X-21 | 4-Nov | 5-Nov | 6-Nov | 7-Nov | 8-Nov | 9-Nov | 10-Nov | 11-Nov | 12-Nov | 13-Nov | 14-Nov | 15-Nov | 16-Nov | 17-Nov | 18-Nov | 19-Nov | 20-Nov | 21-Nov | 22-Nov | 23-Nov | 24-Nov | 25-Nov | 26-Nov | 27-Nov | 28-Nov |
| IBIS | 11 | 0.9 | 38 | 26 | 0 | 0 | 26 | 0 | 58 | 15 | 6.2 | 0 | 0 | 6.2 | 6.2 | 6.2 | 6.2 | 6.2 | 0 | 0 | 25 | 25 | 25 | 0 | 25 |
| STINGRAY | | | | | | | | | | | | | | | | | | | | | | | | | |
| HAMMERHEAD | | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL MHs | 11 | 0.9 | 38 | 26 | 0 | 0 | 26 | 0 | 58 | 15 | 6.2 | 0 | 0 | 6.2 | 6.2 | 6.2 | 6.2 | 6.2 | 0 | 0 | 25 | 25 | 25 | 0 | 25 |

| X-21 | 29-Nov | 30-Nov | 1-Dec | 2-Dec | 3-Dec | 4-Dec | 5-Dec | 6-Dec | 7-Dec | 8-Dec | 9-Dec | 10-Dec | 11-Dec | 12-Dec | 13-Dec | 14-Dec | 15-Dec | 16-Dec | 17-Dec | 18-Dec | 19-Dec | 20-Dec | 21-Dec | 22-Dec | 23-Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IBIS | 0 | 0 | 30 | 25 | 6.2 | 6.2 | 6.2 | 0 | 0 | 6.2 | 6.2 | 6.2 | 45 | 45 | 0 | 0 | 45 | 45 | 17 | 26 | 17 | 0 | 0 | 18 | 17 |
| STINGRAY | | | 11 | 0.9 | 38 | 26 | 0 | 0 | 26 | 0 | 58 | 15 | 6.2 | 0 | 0 | 6.2 | 6.2 | 6.2 | 6.2 | 6.2 | 0 | 0 | 25 | 25 | 25 |
| HAMMERHEAD | | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL MHs | 0 | 0 | 41 | 26 | 44 | 32 | 6.2 | 0 | 26 | 6.2 | 64 | 21 | 51 | 45 | 0 | 6.2 | 51 | 51 | 23 | 32 | 17 | 0 | 25 | 43 | 42 |

| X-21 | 24-Dec | 25-Dec | 26-Dec | 27-Dec | 28-Dec | 29-Dec | 30-Dec | 31-Dec | 1-Jan | 2-Jan | 3-Jan | 4-Jan | 5-Jan | 6-Jan | 7-Jan | 8-Jan | 9-Jan | 10-Jan | 11-Jan | 12-Jan | 13-Jan | 14-Jan | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IBIS | 17 | 0 | 17 | 0 | 0 | 17 | 13 | 4.9 | 0 | 4.9 | 0 | 0 | 0.9 | 0.9 | 0.9 | 0.9 | 17 | 0 | 0 | 17 | 26 | 0.9 | | | |
| STINGRAY | 25 | | 25 | 0 | | 30 | 25 | 6.2 | | 12 | 0 | | 6.2 | 6.2 | 6.2 | 45 | 45 | 0 | | 45 | 45 | 17 | | | |
| HAMMERHEAD | | | | | | | | | | | | | 11 | 0.9 | 38 | 26 | 0 | 0 | 26 | 0 | 58 | 15 | | | |
| TOTAL MHs | 42 | 0 | 42 | 0 | 0 | 47 | 38 | 11 | 0 | 17 | 0 | 0 | 18 | 8.1 | 45 | 72 | 62 | 0 | 26 | 62 | 129 | 32 | | | |

**Figure A.5 Calendar Schedule Representation of Job Shop X-21 Loading over Three Parallel Availabilities.**

| Work Item # | Description | Job Shop | Man-Hours | Date to Complete |
|---|---|---|---|---|
| wi 10 | alignment | x22 | 18.00 | 12/31-1/2 |
| wi 11 | skim cut | x22 | 6.00 | 12/11-12/16 |
| wi 11 | measure final | x22 | 2.00 | 29-Dec |
| wi 11 | measure | x22 | 2.00 | 13-Nov |
| wi 12 | skim cut | x22 | 6.00 | 12/11-12/16 |
| wi 13 | alignment | x22 | 25.00 | 12/17-12/29 |
| wi 14 | alignment | x22 | 6.00 | 12/17-12/29 |
| wi 16 | fit propeller | x22 | 40.00 | 11/14-11/22 |
| wi 16 | renew nut anode | x22 | 4.00 | 29-Dec |
| wi 18 | install (valve/strainers) | x22 | 4.00 | 12/17-12/29 |
| wi 36 | tolerances | x22 | 8.00 | 5-Nov |
| wi 36 | inspect shaft seal | x22 | 92.00 | 11/13-12/16 |
| wi 36 | install (shaft seal) | x22 | 27.00 | 12/17-12/29 |
| wi 36 | remove (shafts) | x22 | 14.00 | 11/6-11/12 |
| | | Total Hours | 254.00 | |

**Table A.7 Job Shop X-22 Subtask Breakdown with man-hours and scheduled completion dates.**

Availability Start Date | Weekends/Holidays

| X-22 | 4-Nov | 5-Nov | 6-Nov | 7-Nov | 8-Nov | 9-Nov | 10-Nov | 11-Nov | 12-Nov | 13-Nov | 14-Nov | 15-Nov | 16-Nov | 17-Nov | 18-Nov | 19-Nov | 20-Nov | 21-Nov | 22-Nov | 23-Nov | 24-Nov | 25-Nov | 26-Nov | 27-Nov | 28-Nov |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IBIS | 0 | 8 | 3.5 | 3.5 | 0 | 0 | 3.5 | 0 | 3.5 | 6 | 11 | 0 | 0 | 11 | 11 | 11 | 11 | 11 | 0 | 0 | 4 | 4 | 4 | 0 | 4 |
| STINGRAY | | | | | | | | | | | | | | | | | | | | | | | | | |
| HAMMERHEAD | | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL MHs | 0 | 8 | 3.5 | 3.5 | 0 | 0 | 3.5 | 0 | 3.5 | 6 | 11 | 0 | 0 | 11 | 11 | 11 | 11 | 11 | 0 | 0 | 4 | 4 | 4 | 0 | 4 |

| X-22 | 29-Nov | 30-Nov | 1-Dec | 2-Dec | 3-Dec | 4-Dec | 5-Dec | 6-Dec | 7-Dec | 8-Dec | 9-Dec | 10-Dec | 11-Dec | 12-Dec | 13-Dec | 14-Dec | 15-Dec | 16-Dec | 17-Dec | 18-Dec | 19-Dec | 20-Dec | 21-Dec | 22-Dec | 23-Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IBIS | 0 | 0 | 4 | 4 | 4 | 4 | 4 | 0 | 0 | 4 | 4 | 4 | 7 | 7 | 0 | 0 | 7 | 7 | 7.8 | 7.8 | 7.8 | 0 | 0 | 7.8 | 7.8 |
| STINGRAY | | | 0 | 8 | 3.5 | 3.5 | 0 | 0 | 3.5 | 0 | 3.5 | 6 | 11 | 0 | 0 | 11 | 11 | 11 | 11 | 11 | 0 | 0 | 4 | 4 | 4 |
| HAMMERHEAD | | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL MHs | 0 | 0 | 4 | 12 | 7.5 | 7.5 | 4 | 0 | 3.5 | 4 | 7.5 | 10 | 18 | 7 | 0 | 11 | 18 | 18 | 18 | 18 | 7.8 | 0 | 4 | 12 | 12 |

| X-22 | 24-Dec | 25-Dec | 26-Dec | 27-Dec | 28-Dec | 29-Dec | 30-Dec | 31-Dec | 1-Jan | 2-Jan | 3-Jan | 4-Jan | 5-Jan | 6-Jan | 7-Jan | 8-Jan | 9-Jan | 10-Jan | 11-Jan | 12-Jan | 13-Jan | 14-Jan | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IBIS | 7.8 | 0 | 7.8 | 0 | 0 | 9.8 | 0 | 9 | 0 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | |
| STINGRAY | 4 | | 4 | 0 | | 4 | 4 | 4 | | 8 | 0 | | 4 | 4 | 4 | 7 | 7 | 0 | | 7 | 7 | 7.8 | | | |
| HAMMERHEAD | | | | | | | | | | | | | 0 | 8 | 3.5 | 3.5 | 0 | 0 | 3.5 | 0 | 3.5 | 6 | | | |
| TOTAL MHs | 12 | 0 | 12 | 0 | 0 | 14 | 4 | 13 | 0 | 17 | 0 | 0 | 4 | 12 | 7.5 | 11 | 7 | 0 | 3.5 | 7 | 11 | 14 | | | |

**Figure A.6 Calendar Schedule Representation of Job Shop X-22 Loading over Three Parallel Availabilities.**

| Work Item # | Description | Job Shop | Man-Hours | Date to Complete |
|---|---|---|---|---|
| wi 10 | protective meas. | x23 | 1.00 | 31-Dec |
| wi 10 | interferences | x23 | 1.00 | 31-Dec |
| wi 10 | insert bolts | x23 | 4.00 | 8-Jan |
| wi 10 | op test | x23 | 10.00 | 1/9-1/13 |
| wi 10 | preparation | x23 | 170.00 | 12/31-1/2 |
| wi 10 | alignment | x23 | 170.00 | 12/31-1/2 |
| wi 10 | final readings | x23 | 4.00 | 1/5-1/8 |
| wi 11 | remove (bearing) | x23 | 8.00 | 11/13-11/22 |
| wi 11 | inspect | x23 | 2.00 | 11/13-11/22 |
| wi 11 | measure | x23 | 2.00 | 11/13-11/22 |
| wi 11 | install (bearing) | x23 | 8.00 | 11/23-12/2 |
| wi 11 | renew fasteners | x23 | 4.00 | 11/23-12/2 |
| wi 11 | verify position | x23 | 4.00 | 11/23-12/2 |
| wi 11 | verify position/optest | x23 | 2.00 | 1/9-1/13 |
| wi 11 | measure final | x23 | 2.00 | 29-Dec |
| wi 12 | remove (bearing) | x23 | 12.00 | 11/13-11/22 |
| wi 12 | inspect | x23 | 8.00 | 11/13-11/22 |
| wi 12 | install (bearing) | x23 | 8.00 | 11/23-12/2 |
| wi 12 | verify position | x23 | 2.00 | 11/23-12/2 |
| wi 13 | remove (bearing) | x23 | 10.00 | 11/13-11/22 |
| wi 13 | renew chock fast | x23 | 10.00 | 11/23-12/2 |
| wi 13 | verify alignment | x23 | 2.00 | 11/23-12/2 |
| wi 13 | alignment | x23 | 10.00 | 11/23-12/2 |
| wi 14 | remove (bearing) | x23 | 16.00 | 11/13-11/22 |
| wi 14 | alignment | x23 | 20.00 | 11/23-12/2 |
| wi 16 | install (propeller) | x23 | 20.00 | 12/17-12/29 |
| wi 16 | lock propeller nut | x23 | 4.00 | 29-Dec |
| wi 16 | reinstall (fairing plate) | x23 | 8.00 | 12/26-12/29 |
| wi 16 | inspect GFE | x23 | 4.00 | 11/13-11/22 |
| wi 16 | renew nut anode | x23 | 8.00 | 12/26-12/29 |
| wi 16 | protective meas. | x23 | 4.00 | 11/6-11/12 |
| wi 16 | remove (propeller) | x23 | 20.00 | 11/6-11/12 |
| wi 19 | renew rudder asmb | x23 | 22.00 | 12/17-12/29 |
| wi 19 | alignment | x23 | 10.00 | 12/31-1/13 |
| wi 19 | op test | x23 | 2.00 | 12/31-1/13 |
| wi 20 | protective meas. | x23 | 2.00 | 11/6-11/12 |
| wi 20 | op test final | x23 | 4.00 | 29-Dec |
| wi 20 | interferences | x23 | 4.00 | 11/6-11/12 |
| wi 20 | op test initial | x23 | 2.00 | 5-Nov |
| wi 20 | visual inspection | x23 | 2.00 | 6-Nov |
| wi 20 | install (stern launch door) | x23 | 40.00 | 18-Dec |
| wi 20 | remove (stern launch door) | x23 | 26.00 | 11/6-11/12 |
| wi 25 | reinstalls | x23 | 12.00 | 12/11-12/16 |
| wi 25 | preps/removals | x23 | 12.00 | 13-Nov |
| wi 26 | preparation | x23 | 10.00 | 13-Nov |
| wi 26 | reinstalls | x23 | 10.00 | 12/11-12/16 |
| wi 30 | dry dock vsl | x23 | 27.00 | 6-Nov |
| wi 32 | sea trials | x23 | 48.00 | 1/9-1/13 |
| wi 32 | ride in | x23 | 8.00 | 4-Nov |
| wi 34 | preps/removals | x23 | 4.00 | 13-Nov |
| wi 34 | reinstalls | x23 | 4.00 | 12/11-12/16 |
| wi 36 | pre-docking alignment | x23 | 10.00 | 11/4-11/5 |
| wi 36 | visual inspection | x23 | 2.00 | 11/6-11/12 |
| wi 36 | alignment | x23 | 80.00 | 11/23-12/16 |
| wi 36 | bearing clearance check | x23 | 4.00 | 12/17-12/29 |
| wi 36 | hub alignment check | x23 | 4.00 | 11/4-11/5 |
| wi 36 | op test | x23 | 4.00 | 1/9-1/13 |
| wi 36 | inspections | x23 | 16.00 | 11/6-11/23 |
| wi 36 | inspect shaft seal | x23 | 16.00 | 11/13-12/16 |
| wi 36 | install (shaft seal) | x23 | 16.00 | 12/17-12/29 |
| wi 36 | protective meas. | x23 | 4.00 | 11/6-11/12 |
| wi 36 | install (shaft asmb) | x23 | 40.00 | 12/17-12/29 |
| wi 36 | interferences | x23 | 8.00 | 11/6-11/12 |
| wi 36 | remove (shafts) | x23 | 16.00 | 11/6-11/12 |
| wi 37 | remove (transducers) | x23 | 9.00 | 11/6-11/12 |
| wi 37 | remove gfe | x23 | 10.00 | 11/13-11/22 |
| wi 37 | resintall transducer | x23 | 9.00 | 12/17-12/29 |
| wi 3b | remove (electric) | x23 | 8.00 | 11/23-12/2 |
| wi 3b | remove (towing) | x23 | 8.00 | 11/23-12/2 |
| wi 3b | install (electric) | x23 | 8.00 | 12/11-12/16 |
| wi 3b | install (towing) | x23 | 8.00 | 12/11-12/16 |
| wi 3b | remove (steering) | x23 | 48.00 | 11/23-12/2 |
| wi 3b | remove (bilge) | x23 | 8.00 | 11/23-12/2 |
| wi 3b | remove (l/o) | x23 | 12.00 | 11/23-12/2 |
| wi 3b | install (steering) | x23 | 48.00 | 12/11-12/16 |
| wi 3b | install (bilge) | x23 | 8.00 | 12/11-12/16 |
| wi 3b | install (l/o) | x23 | 12.00 | 12/11-12/16 |
| wi 4b | reinstalls | x23 | 18.00 | 12/11-12/16 |
| wi 4b | preps/removals | x23 | 18.00 | 11/23-12/2 |
| | | Total Hours | 1259.00 | |

**Table A.8 Job Shop X-23 Subtask Breakdown with man-hours and scheduled completion dates.**

Availability Start Date | Weekends/Holidays

| X-23 | 4-Nov | 5-Nov | 6-Nov | 7-Nov | 8-Nov | 9-Nov | 10-Nov | 11-Nov | 12-Nov | 13-Nov | 14-Nov | 15-Nov | 16-Nov | 17-Nov | 18-Nov | 19-Nov | 20-Nov | 21-Nov | 22-Nov | 23-Nov | 24-Nov | 25-Nov | 26-Nov | 27-Nov | 28-Nov |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IBIS | 15 | 9 | 54 | 25 | 0 | 0 | 25 | 0 | 25 | 38 | 12 | 0 | 0 | 12 | 12 | 12 | 12 | 12 | 0 | 0 | 34 | 34 | 34 | 0 | 34 |
| STINGRAY | | | | | | | | | | | | | | | | | | | | | | | | | |
| HAMMERHEAD | | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL MHs | 15 | 9 | 54 | 25 | 0 | 0 | 25 | 0 | 25 | 38 | 12 | 0 | 0 | 12 | 12 | 12 | 12 | 12 | 0 | 0 | 34 | 34 | 34 | 0 | 34 |
| X-23 | 29-Nov | 30-Nov | 1-Dec | 2-Dec | 3-Dec | 4-Dec | 5-Dec | 6-Dec | 7-Dec | 8-Dec | 9-Dec | 10-Dec | 11-Dec | 12-Dec | 13-Dec | 14-Dec | 15-Dec | 16-Dec | 17-Dec | 18-Dec | 19-Dec | 20-Dec | 21-Dec | 22-Dec | 23-Dec |
| IBIS | 0 | 0 | 34 | 34 | 5.7 | 5.7 | 5.7 | 0 | 0 | 5.7 | 5.7 | 5.7 | 38 | 38 | 0 | 0 | 38 | 38 | 19 | 19 | 19 | 0 | 0 | 19 | 19 |
| STINGRAY | | | 15 | 9 | 54 | 25 | 0 | 0 | 25 | 0 | 25 | 38 | 12 | 0 | 0 | 12 | 12 | 12 | 12 | 12 | 0 | 0 | 34 | 34 | 34 |
| HAMMERHEAD | | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL MHs | 0 | 0 | 49 | 43 | 60 | 31 | 5.7 | 0 | 25 | 5.7 | 31 | 44 | 50 | 38 | 0 | 12 | 50 | 50 | 31 | 31 | 19 | 0 | 34 | 53 | 53 |
| X-23 | 24-Dec | 25-Dec | 26-Dec | 27-Dec | 28-Dec | 29-Dec | 30-Dec | 31-Dec | 1-Jan | 2-Jan | 3-Jan | 4-Jan | 5-Jan | 6-Jan | 7-Jan | 8-Jan | 9-Jan | 10-Jan | 11-Jan | 12-Jan | 13-Jan | 14-Jan | | | |
| IBIS | 19 | 0 | 27 | 0 | 0 | 37 | 0 | 60 | 0 | 58 | 0 | 0 | 59 | 59 | 59 | 63 | 23 | 0 | 0 | 23 | 23 | 0 | | | |
| STINGRAY | 34 | | 34 | 0 | | 34 | 34 | 5.7 | | 11 | 0 | | 5.7 | 5.7 | 5.7 | 38 | 38 | 0 | | 38 | 38 | 19 | | | |
| HAMMERHEAD | | | | | | | | | | | | | 15 | 9 | 54 | 25 | 0 | 0 | 25 | 0 | 25 | 38 | | | |
| TOTAL MHs | 53 | 0 | 61 | 0 | 0 | 71 | 34 | 66 | 0 | 69 | 0 | 0 | 80 | 74 | 119 | 126 | 60 | 0 | 25 | 60 | 86 | 57 | | | |

**Figure A.7 Calendar Schedule Representation of Job Shop X-23 Loading over Three Parallel Availabilities.**

| Work Item # | Description | Job Shop | Man-Hours | Date to Complete |
|---|---|---|---|---|
| wi 25 | preps/removals | x24 | 6.00 | 11/6-11/13 |
| wi 26 | preparation | x24 | 6.00 | 11/6-11/13 |
| wi 30 | undock vsl | x24 | 18.00 | 30-Dec |
| wi 30 | dry dock vsl | x24 | 18.00 | 6-Nov |
| | | Total Hours | 48.00 | |

**Table A.9 Job Shop X-24 Subtask Breakdown with man-hours and scheduled completion dates.**

Availability Start Date | Weekends/Holidays

| X-24 | 4-Nov | 5-Nov | 6-Nov | 7-Nov | 8-Nov | 9-Nov | 10-Nov | 11-Nov | 12-Nov | 13-Nov | 14-Nov | 15-Nov | 16-Nov | 17-Nov | 18-Nov | 19-Nov | 20-Nov | 21-Nov | 22-Nov | 23-Nov | 24-Nov | 25-Nov | 26-Nov | 27-Nov | 28-Nov |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IBIS | | | 18 | 3 | | | 3 | | 3 | 3 | | | | | | | | | | | | | | | |
| STINGRAY | | | | | | | | | | | | | | | | | | | | | | | | | |
| HAMMERHEAD | | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL MHs | 0 | 0 | 18 | 3 | 0 | 0 | 3 | 0 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| X-24 | 29-Nov | 30-Nov | 1-Dec | 2-Dec | 3-Dec | 4-Dec | 5-Dec | 6-Dec | 7-Dec | 8-Dec | 9-Dec | 10-Dec | 11-Dec | 12-Dec | 13-Dec | 14-Dec | 15-Dec | 16-Dec | 17-Dec | 18-Dec | 19-Dec | 20-Dec | 21-Dec | 22-Dec | 23-Dec |
| IBIS | | | | | | | | | | | | | | | | | | | | | | | | | |
| STINGRAY | | | | | 18 | 3 | | | 3 | | 3 | 3 | | | | | | | | | | | | | |
| HAMMERHEAD | | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL MHs | 0 | 0 | 0 | 0 | 18 | 3 | 0 | 0 | 3 | 0 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| X-24 | 24-Dec | 25-Dec | 26-Dec | 27-Dec | 28-Dec | 29-Dec | 30-Dec | 31-Dec | 1-Jan | 2-Jan | 3-Jan | 4-Jan | 5-Jan | 6-Jan | 7-Jan | 8-Jan | 9-Jan | 10-Jan | 11-Jan | 12-Jan | 13-Jan | 14-Jan | | | |
| IBIS | | | | | | | 18 | | | | | | | | | | | | | | | | | | |
| STINGRAY | | | | | | | | | | | | | | | | | | | | | | | | | |
| HAMMERHEAD | | | | | | | | | | | | | | | 18 | 3 | | | 3 | | 3 | 3 | | | |
| TOTAL MHs | 0 | 0 | 0 | 0 | 0 | 0 | 18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 18 | 3 | 0 | 0 | 3 | 0 | 3 | 3 | | | |

**Figure A.8 Calendar Schedule Representation of Job Shop X-24 Loading over Three Parallel Availabilities.**

| Work Item # | Description | Job Shop | Man-Hours | Date to Complete |
|---|---|---|---|---|
| support service per day | | x31 | | |
| support services | | x31 | 80.00 | 1.7 |
| wi 17 | remove (exhaust lagging) | x31 | 8.00 | 12/1-12/16 |
| wi 17 | install/test | x31 | 8.00 | 12/17-12/29 |
| wi 19 | renew rudder asmb | x31 | 2.00 | 12/17-12/29 |
| wi 19 | alignment | x31 | 2.00 | 12/31-1/13 |
| wi 19 | op test | x31 | 2.00 | 12/31-1/13 |
| wi 20 | op test | x31 | 2.00 | 5-Nov |
| wi 20 | visual inspection | x31 | 1.00 | 6-Nov |
| wi 20 | remove (stern launch door) | x31 | 3.00 | 11/6-11/12 |
| wi 20 | install (stern launch door) | x31 | 6.00 | 18-Dec |
| wi 21 | close tanks | x31 | 6.00 | 12/11-12/16 |
| wi 21 | open tanks | x31 | 2.00 | 5-Nov |
| wi 21 | inspect tanks | x31 | 6.00 | 12-Nov |
| wi 21 | final inspect | x31 | 3.00 | 12/11-12/16 |
| wi 22 | open tanks | x31 | 2.00 | 5-Nov |
| wi 22 | close tanks | x31 | 6.00 | 12/11-12/16 |
| wi 22 | inspect tanks | x31 | 6.00 | 12-Nov |
| wi 22 | final inspect | x31 | 3.00 | 12/11-12/16 |
| wi 23 | install (spool) | x31 | 3.00 | 12/11-12/16 |
| wi 23 | install (tank valves) | x31 | 3.00 | 12/11-12/16 |
| wi 24 | install (spool) | x31 | 3.00 | 12/11-12/16 |
| wi 24 | install (tank valves) | x31 | 3.00 | 12/11-12/16 |
| wi 26 | reinstalls | x31 | 6.00 | 12/11-12/16 |
| wi 27 | preps/removals | x31 | 80.00 | 11/6-11/12 |
| wi 27 | reinstalls | x31 | 100.00 | 12/11-12/16 |
| wi 28 | preps/removals | x31 | 16.00 | 11/6-11/13 |
| wi 28 | reinstalls | x31 | 16.00 | 12/11-12/16 |
| wi 29 | renew zinc anodes | x31 | 6.00 | 12/11-12/16 |
| wi 30 | undock vsl | x31 | 18.00 | 30-Dec |
| wi 30 | dry dock vsl | x31 | 27.00 | 6-Nov |
| wi 31 | connect temp services | x31 | 9.00 | 6-Nov |
| wi 31 | final removals | x31 | 9.00 | 13-Jan |
| wi 32 | sea trials | x31 | 48.00 | 1/9-1/13 |
| wi 32 | ride in | x31 | 8.00 | 4-Nov |
| wi 33 | crop/renew | x31 | 6.00 | 11/23-12/2 |
| wi 34 | preps/removals | x31 | 4.00 | 13-Nov |
| wi 34 | reinstalls | x31 | 4.00 | 12/11-12/16 |
| wi 36 | op test | x31 | 4.00 | 1/9-1/13 |
| wi 36 | protective meas. | x31 | 2.00 | 11/6-11/12 |
| wi 36 | interferences | x31 | 2.00 | 11/6-11/12 |
| wi 3b | remove (electric) | x31 | 8.00 | 11/23-12/2 |
| wi 3b | install (electric) | x31 | 8.00 | 12/11-12/16 |
| wi 3b | remove (steering) | x31 | 3.00 | 11/23-12/2 |
| wi 3b | remove (bilge) | x31 | 8.00 | 11/23-12/2 |
| wi 3b | install (steering) | x31 | 3.00 | 12/11-12/16 |
| wi 3b | install (bilge) | x31 | 8.00 | 12/11-12/16 |
| wi 4b | reinstalls | x31 | 16.00 | 12/11-12/16 |
| wi 4b | preps/removals | x31 | 16.00 | 11/23-12/2 |
| wi 5 | open tanks | x31 | 2.00 | 5-Nov |
| wi 5 | close tanks | x31 | 2.00 | 12/11-12/16 |
| wi 5 | inspect tanks | x31 | 3.00 | 12-Nov |
| wi 5 | final inspect | x31 | 3.00 | 12/11-12/16 |
| wi 6 | close tanks | x31 | 2.00 | 12/11-12/16 |
| wi 6 | final inspect | x31 | 3.00 | 12/11-12/16 |
| wi 6 | open tanks | x31 | 2.00 | 5-Nov |
| wi 6 | inspect tanks | x31 | 3.00 | 12-Nov |
| wi 7 | open tanks | x31 | 4.00 | 5-Nov |
| wi 7 | close tanks | x31 | 2.00 | 12/11-12/16 |
| wi 7 | inspect tanks | x31 | 6.00 | 12-Nov |
| wi 7 | final inspect | x31 | 6.00 | 12/11-12/16 |
| wi 8 | open tanks | x31 | 2.00 | 5-Nov |
| wi 8 | inspect tanks | x31 | 4.00 | 12-Nov |
| wi 8 | final inspect | x31 | 2.00 | 12/11-12/16 |
| wi 8 | close tanks | x31 | 2.00 | 12/11-12/16 |
| | | Total Hours | 643.00 | |

**Table A.10 Job Shop X-31 Subtask Breakdown with man-hours and scheduled completion dates.**

| X-31 | 4-Nov | 5-Nov | 6-Nov | 7-Nov | 8-Nov | 9-Nov | 10-Nov | 11-Nov | 12-Nov | 13-Nov | 14-Nov | 15-Nov | 16-Nov | 17-Nov | 18-Nov | 19-Nov | 20-Nov | 21-Nov | 22-Nov | 23-Nov | 24-Nov | 25-Nov | 26-Nov | 27-Nov | 28-Nov |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IBIS | 9.7 | 18 | 64 | 27 | 0 | 0 | 27 | 0 | 55 | 8.9 | 1.7 | 0 | 0 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 0 | 0 | 8.5 | 8.5 | 8.5 | 0 | 8.5 |
| STINGRAY | | | | | | | | | | | | | | | | | | | | | | | | | |
| HAMMERHEAD | | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL MHs | 9.7 | 18 | 64 | 27 | 0 | 0 | 27 | 0 | 55 | 8.9 | 1.7 | 0 | 0 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 0 | 0 | 8.5 | 8.5 | 8.5 | 0 | 8.5 |

| X-31 | 29-Nov | 30-Nov | 1-Dec | 2-Dec | 3-Dec | 4-Dec | 5-Dec | 6-Dec | 7-Dec | 8-Dec | 9-Dec | 10-Dec | 11-Dec | 12-Dec | 13-Dec | 14-Dec | 15-Dec | 16-Dec | 17-Dec | 18-Dec | 19-Dec | 20-Dec | 21-Dec | 22-Dec | 23-Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IBIS | 0 | 0 | 9.2 | 9.2 | 2.4 | 2.4 | 2.4 | 0 | 0 | 2.4 | 2.4 | 2.4 | 57 | 57 | 0 | 0 | 57 | 57 | 3.7 | 3.7 | 3.7 | 0 | 0 | 3.7 | 3.7 |
| STINGRAY | | | 9.7 | 18 | 64 | 27 | 0 | 0 | 27 | 0 | 55 | 8.9 | 1.7 | 0 | 0 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 0 | 0 | 8.5 | 8.5 | 8.5 |
| HAMMERHEAD | | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL MHs | 0 | 0 | 19 | 27 | 66 | 29 | 2.4 | 0 | 27 | 2.4 | 57 | 11 | 59 | 57 | 0 | 1.7 | 59 | 59 | 5.4 | 5.4 | 3.7 | 0 | 8.5 | 12 | 12 |

| X-31 | 24-Dec | 25-Dec | 26-Dec | 27-Dec | 28-Dec | 29-Dec | 30-Dec | 31-Dec | 1-Jan | 2-Jan | 3-Jan | 4-Jan | 5-Jan | 6-Jan | 7-Jan | 8-Jan | 9-Jan | 10-Jan | 11-Jan | 12-Jan | 13-Jan | 14-Jan | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IBIS | 3.7 | 0 | 3.7 | 0 | 0 | 3.7 | 20 | 2.1 | 0 | 2.1 | 0 | 0 | 2.1 | 2.1 | 2.1 | 2.1 | 28 | 0 | 0 | 19 | 19 | 1.7 | | | |
| STINGRAY | 8.5 | | 8.5 | 0 | | 9.2 | 9.2 | 2.4 | | 4.8 | 0 | | 2.4 | 2.4 | 2.4 | 57 | 57 | 0 | | 57 | 57 | 3.7 | | | |
| HAMMERHEAD | | | | | | | | | | | | | 9.7 | 18 | 64 | 27 | 0 | 0 | 27 | 0 | 55 | 8.9 | | | |
| TOTAL MHs | 12 | 0 | 12 | 0 | 0 | 13 | 29 | 4.5 | 0 | 6.9 | 0 | 0 | 14 | 22 | 68 | 86 | 86 | 0 | 27 | 77 | 131 | 14 | | | |

**Figure A.9 Calendar Schedule Representation of Job Shop X-31 Loading over Three Parallel Availabilities.**

| Work Item # | Description | Job Shop | Man-Hours | Date to Complete |
|---|---|---|---|---|
| wi 19 | renew rudder asmb | x32 | 2.00 | 12/17-12/29 |
| wi 19 | alignment | x32 | 2.00 | 12/31-1/13 |
| wi 19 | op test | x32 | 2.00 | 12/31-1/13 |
| wi 27 | preps/removals | x32 | 36.00 | 11/6-11/12 |
| wi 27 | reinstalls | x32 | 45.00 | 12/17-12/29 |
| wi 28 | preps/removals | x32 | 22.00 | 11/6-11/13 |
| wi 28 | reinstalls | x32 | 22.00 | 12/11-12/29 |
| wi 31 | ekms services | x32 | 45.00 | |
| wi 32 | sea trials | x32 | 24.00 | 1/9-1/13 |
| wi 32 | ride in | x32 | 8.00 | 4-Nov |
| wi 37 | inspect speed log asmb | x32 | 2.00 | 11/6-11/12 |
| wi 37 | op test | x32 | 2.00 | 12/31-1/2 |
| wi 37 | remove (transducers) | x32 | 9.00 | 11/6-11/12 |
| wi 37 | resintall transducer | x32 | 9.00 | 12/17-12/29 |
| | | Total Hours | 230.00 | |

**Table A.11 Job Shop X-32 Subtask Breakdown with man-hours and scheduled completion dates.**

Availability Start Date | Weekends/Holidays

| X-32 | 4-Nov | 5-Nov | 6-Nov | 7-Nov | 8-Nov | 9-Nov | 10-Nov | 11-Nov | 12-Nov | 13-Nov | 14-Nov | 15-Nov | 16-Nov | 17-Nov | 18-Nov | 19-Nov | 20-Nov | 21-Nov | 22-Nov | 23-Nov | 24-Nov | 25-Nov | 26-Nov | 27-Nov | 28-Nov |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IBIS | 8.9 | 0.9 | 17 | 17 | 0 | 0 | 17 | 0 | 17 | 5.3 | 0.9 | 0 | 0 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0 | 0 | 0.9 | 0.9 | 0.9 | 0 | 0.9 |
| STINGRAY | | | | | | | | | | | | | | | | | | | | | | | | | |
| HAMMERHEAD | | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL MHs | 8.9 | 0.9 | 17 | 17 | 0 | 0 | 17 | 0 | 17 | 5.3 | 0.9 | 0 | 0 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0 | 0 | 0.9 | 0.9 | 0.9 | 0 | 0.9 |

| X-32 | 29-Nov | 30-Nov | 1-Dec | 2-Dec | 3-Dec | 4-Dec | 5-Dec | 6-Dec | 7-Dec | 8-Dec | 9-Dec | 10-Dec | 11-Dec | 12-Dec | 13-Dec | 14-Dec | 15-Dec | 16-Dec | 17-Dec | 18-Dec | 19-Dec | 20-Dec | 21-Dec | 22-Dec | 23-Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IBIS | 0 | 0 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0 | 0 | 0.9 | 0.9 | 0.9 | 2.7 | 2.7 | 0 | 0 | 2.7 | 2.7 | 9.7 | 9.7 | 9.7 | 0 | 0 | 9.7 | 9.7 |
| STINGRAY | | | 8.9 | 0.9 | 17 | 17 | 0 | 0 | 17 | 0 | 17 | 5.3 | 0.9 | 0 | 0 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0 | 0 | 0.9 | 0.9 | 0.9 |
| HAMMERHEAD | | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL MHs | 0 | 0 | 9.8 | 1.8 | 18 | 18 | 0.9 | 0 | 17 | 0.9 | 18 | 6.2 | 3.6 | 2.7 | 0 | 0.9 | 3.6 | 3.6 | 11 | 11 | 9.7 | 0 | 0.9 | 11 | 11 |

| X-32 | 24-Dec | 25-Dec | 26-Dec | 27-Dec | 28-Dec | 29-Dec | 30-Dec | 31-Dec | 1-Jan | 2-Jan | 3-Jan | 4-Jan | 5-Jan | 6-Jan | 7-Jan | 8-Jan | 9-Jan | 10-Jan | 11-Jan | 12-Jan | 13-Jan | 14-Jan | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IBIS | 9.7 | 0 | 9.7 | 0 | 0 | 9.7 | 0.9 | 2.9 | 0 | 2.9 | 0 | 0 | 2.9 | 0.9 | 0.9 | 0.9 | 8.9 | 0 | 0 | 8.9 | 8.9 | 0.9 | | | |
| STINGRAY | 0.9 | 0 | 0.9 | 0 | 0 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0 | 0 | 0.9 | 0.9 | 0.9 | 2.7 | 2.7 | 0 | 0 | 2.7 | 2.7 | 9.7 | | | |
| HAMMERHEAD | | | | | | | | | | | | | 8.9 | 0.9 | 17 | 17 | 0 | 0 | 17 | 0 | 17 | 5.3 | | | |
| TOTAL MHs | 11 | 0 | 11 | 0 | 0 | 11 | 1.8 | 3.8 | 0.9 | 3.8 | 0 | 0 | 13 | 2.7 | 19 | 21 | 12 | 0 | 17 | 12 | 29 | 16 | | | |

**Figure A.10 Calendar Schedule Representation of Job Shop X-32 Loading over Three Parallel Availabilities.**

| Work Item # | Description | Job Shop | Man-Hours | Date to Complete |
|---|---|---|---|---|
| wi 31 | connect temp services | x33 | 8.00 | 6-Nov |
| wi 31 | final removals | x33 | 8.00 | 13-Jan |
| | | Total Hours | 16.00 | |

**Table A.12 Job Shop X-33 Subtask Breakdown with man-hours and scheduled completion dates.**

Availability Start Date | Weekends/Holidays

| X-33 | 4-Nov | 5-Nov | 6-Nov | 7-Nov | 8-Nov | 9-Nov | 10-Nov | 11-Nov | 12-Nov | 13-Nov | 14-Nov | 15-Nov | 16-Nov | 17-Nov | 18-Nov | 19-Nov | 20-Nov | 21-Nov | 22-Nov | 23-Nov | 24-Nov | 25-Nov | 26-Nov | 27-Nov | 28-Nov |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IBIS | | | 8 | | | | | | | | | | | | | | | | | | | | | | |
| STINGRAY | | | | | | | | | | | | | | | | | | | | | | | | | |
| HAMMERHEAD | | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL MHs | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| X-33 | 29-Nov | 30-Nov | 1-Dec | 2-Dec | 3-Dec | 4-Dec | 5-Dec | 6-Dec | 7-Dec | 8-Dec | 9-Dec | 10-Dec | 11-Dec | 12-Dec | 13-Dec | 14-Dec | 15-Dec | 16-Dec | 17-Dec | 18-Dec | 19-Dec | 20-Dec | 21-Dec | 22-Dec | 23-Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IBIS | | | | | | | | | | | | | | | | | | | | | | | | | |
| STINGRAY | | | | | 8 | | | | | | | | | | | | | | | | | | | | |
| HAMMERHEAD | | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL MHs | 0 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| X-33 | 24-Dec | 25-Dec | 26-Dec | 27-Dec | 28-Dec | 29-Dec | 30-Dec | 31-Dec | 1-Jan | 2-Jan | 3-Jan | 4-Jan | 5-Jan | 6-Jan | 7-Jan | 8-Jan | 9-Jan | 10-Jan | 11-Jan | 12-Jan | 13-Jan | 14-Jan | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IBIS | | | | | | | | | | | | | | | | | | | | | 8 | | | | |
| STINGRAY | | | | | | | | | | | | | | | | | | | | | | | | | |
| HAMMERHEAD | | | | | | | | | | | | | | | 8 | | | | | | | | | | |
| TOTAL MHs | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 8 | 0 | | | |

**Figure A.11 Calendar Schedule Representation of Job Shop X-33 Loading over Three Parallel Availabilities.**

| Work Item # | Description | Job Shop | Man-Hours | Date to Complete |
|---|---|---|---|---|
| support service per day | | x41 | | |
| support services | | x41 | 27.00 | 0.5625 |
| wi 15 | preparation | x41 | 16.00 | 11/6-11/13 |
| wi 16 | fit propeller | x41 | 8.00 | 11/14-11/22 |
| wi 16 | install (propeller) | x41 | 10.00 | 12/17-12/29 |
| wi 16 | protective meas. | x41 | 4.00 | 11/6-11/12 |
| wi 16 | remove (propeller) | x41 | 12.00 | 11/6-11/12 |
| wi 27 | preps/removals | x41 | 10.00 | 11/6-11/12 |
| wi 27 | reinstalls | x41 | 10.00 | 12/11-12/16 |
| wi 28 | preps/removals | x41 | 50.00 | 11/6-12/10 |
| wi 28 | reinstalls | x41 | 18.00 | 12/11-12/16 |
| wi 31 | connect temp services | x41 | 26.00 | 11/6-11/12 |
| wi 31 | final removals | x41 | 12.00 | 12/30-1/14 |
| wi 33 | crop/renew | x41 | 10.00 | 11/23-12/2 |
| wi 34 | non-skid | x41 | 120.00 | 12/11-12/16 |
| wi 36 | protective meas. | x41 | 3.00 | 11/6-11/12 |
| wi 36 | interferences | x41 | 3.00 | 11/6-11/12 |
| wi 36 | remove (shafts) | x41 | 4.00 | 11/6-11/12 |
| wi 3b | cut access holes | x41 | 36.00 | 11/23-12/2 |
| wi 3b | reinstalls | x41 | 36.00 | 12/11-12/16 |
| wi 9 | preps/removals | x41 | 16.00 | 11/6-11/12 |
| | | Total Hours | 431.00 | |

Table A.13 Job Shop X-41 Subtask Breakdown with man-hours and scheduled completion dates.

| | Availability Start Date | | | | | | Weekends/Holidays | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| X-41 | 4-Nov | 5-Nov | 6-Nov | 7-Nov | 8-Nov | 9-Nov | 10-Nov | 11-Nov | 12-Nov | 13-Nov | 14-Nov | 15-Nov | 16-Nov | 17-Nov | 18-Nov | 19-Nov | 20-Nov | 21-Nov | 22-Nov | 23-Nov | 24-Nov | 25-Nov | 26-Nov | 27-Nov | 28-Nov |
| IBIS | 0.6 | 0.6 | 25.3 | 25.3 | 0 | 0 | 25.3 | 0 | 25.3 | 5.8 | 4.6 | 0 | 0 | 4.6 | 4.6 | 4.6 | 2.6 | 2.6 | 0 | 0 | 10 | 10 | 10 | 0 | 10 |
| STINGRAY | | | | | | | | | | | | | | | | | | | | | | | | | |
| HAMMERHEAD | | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL MHs | 0.6 | 0.6 | 25.3 | 25.3 | 0 | 0 | 25.3 | 0 | 25.3 | 5.8 | 4.6 | 0 | 0 | 4.6 | 4.6 | 4.6 | 2.6 | 2.6 | 0 | 0 | 10 | 10 | 10 | 0 | 10 |
| X-41 | 29-Nov | 30-Nov | 1-Dec | 2-Dec | 3-Dec | 4-Dec | 5-Dec | 6-Dec | 7-Dec | 8-Dec | 9-Dec | 10-Dec | 11-Dec | 12-Dec | 13-Dec | 14-Dec | 15-Dec | 16-Dec | 17-Dec | 18-Dec | 19-Dec | 20-Dec | 21-Dec | 22-Dec | 23-Dec |
| IBIS | 0 | 0 | 10.3 | 10.3 | 2.6 | 2.6 | 2.56 | 0 | 0 | 2.6 | 2.6 | 2.6 | 47 | 47 | 0 | 0 | 47 | 47 | 5.6 | 5.6 | 0.6 | 0 | 0 | 0.6 | 0.6 |
| STINGRAY | | | 0.56 | 0.56 | 25 | 25 | 0 | 0 | 25.3 | 0 | 25 | 5.8 | 4.6 | 0 | 0 | 4.6 | 4.6 | 4.6 | 2.6 | 2.6 | 0 | 0 | 10 | 10 | 10 |
| HAMMERHEAD | | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL MHs | 0 | 0 | 10.8 | 10.8 | 28 | 28 | 2.56 | 0 | 25.3 | 2.6 | 28 | 8.3 | 51 | 47 | 0 | 4.6 | 51 | 51 | 8.1 | 8.1 | 0.6 | 0 | 10 | 11 | 11 |
| X-41 | 24-Dec | 25-Dec | 26-Dec | 27-Dec | 28-Dec | 29-Dec | 30-Dec | 31-Dec | 1-Jan | 2-Jan | 3-Jan | 4-Jan | 5-Jan | 6-Jan | 7-Jan | 8-Jan | 9-Jan | 10-Jan | 11-Jan | 12-Jan | 13-Jan | 14-Jan | | | |
| IBIS | 0.6 | 0 | 0.56 | 0 | 0 | 0.6 | 6.56 | 2.6 | 0 | 2.6 | 0 | 0 | 2.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0 | 0 | 0.6 | 0.6 | 0.6 | | | |
| STINGRAY | 10 | | 10.3 | 0 | | 10 | 10.3 | 2.6 | | 5.2 | 0 | | 2.6 | 2.6 | 2.6 | 47 | 47 | 0 | | 47 | 47 | 5.6 | | | |
| HAMMERHEAD | | | | | | | | | | | | | 0.6 | 0.6 | 25 | 25 | 0 | 0 | 25 | 0 | 25 | 5.8 | | | |
| TOTAL MHs | 11 | 0 | 10.8 | 0 | 0 | 11 | 16.8 | 5.1 | 0 | 7.8 | 0 | 0 | 5.7 | 3.7 | 28 | 72 | 47 | 0 | 25 | 47 | 72 | 12 | | | |

Figure A.12 Calendar Schedule Representation of Job Shop X-41 Loading over Three Parallel Availabilities.

| Work Item # | Description | Job Shop | Man-Hours | Date to Complete |
|---|---|---|---|---|
| wi 1 | prime coat | x42 | 24.00 | 11/14-11/22 |
| wi 10 | op test | x42 | 4.00 | 5-Jan |
| wi 15 | grit blast | x42 | 16.00 | 11/14-11/22 |
| wi 15 | coatings | x42 | 12.00 | 11/14-11/22 |
| wi 15 | preparation | x42 | 16.00 | 11/6-11/12 |
| wi 18 | clean/inspect | x42 | 24.00 | 11/13-12/1 |
| wi 20 | prep/coat | x42 | 16.00 | 12/22-12/24 |
| wi 21 | final inspect | x42 | 2.00 | 12/11-12/16 |
| wi 22 | final inspect | x42 | 2.00 | 12/11-12/16 |
| wi 25 | blast | x42 | 280.00 | 11/14-11/22 |
| wi 25 | coatings | x42 | 118.00 | 12/1-12/10 |
| wi 25 | reinstalls | x42 | 42.00 | 12/11-12/16 |
| wi 25 | preps/removals | x42 | 108.00 | 13-Nov |
| wi 26 | coatings | x42 | 142.00 | 12/1-12/10 |
| wi 26 | decals | x42 | 16.00 | 12/11-12/16 |
| wi 26 | preparation | x42 | 250.00 | 13-Nov |
| wi 26 | reinstalls | x42 | 6.00 | 12/11-12/16 |
| wi 27 | coatings | x42 | 90.00 | 12/1-12/10 |
| wi 27 | reinstalls | x42 | 8.00 | 12/11-12/16 |
| wi 28 | coatings | x42 | 160.00 | 12/1-12/10 |
| wi 28 | preps/removals | x42 | 196.00 | 11/6-11/13 |
| wi 28 | reinstalls | x42 | 16.00 | 12/11-12/16 |
| wi 29 | renew zinc anodes | x42 | 8.00 | 12/11-12/16 |
| wi 30 | undock vsl | x42 | 21.00 | 30-Dec |
| wi 30 | dry dock vsl | x42 | 42.00 | 6-Nov |
| wi 33 | crop/renew | x42 | 18.00 | 11/23-12/2 |
| wi 34 | jet blast | x42 | 240.00 | 11/14-11/22 |
| wi 34 | coatings | x42 | 154.00 | 12/1-12/10 |
| wi 34 | non-skid | x42 | 14.00 | 12/11-12/16 |
| wi 34 | preps/removals | x42 | 16.00 | 11/6-11/13 |
| wi 34 | reinstalls | x42 | 16.00 | 12/11-12/16 |
| wi 35 | install/test/preserve | x42 | 12.00 | 12/17-12/29 |
| wi 36 | inspections | x42 | 2.00 | 11/6-11/12 |
| wi 3b | blast | x42 | 60.00 | 11/14-11/22 |
| wi 3b | powertool | x42 | 20.00 | 11/23-12/2 |
| wi 3b | coatings | x42 | 48.00 | 12/1-12/10 |
| wi 3b | cut access holes | x42 | 24.00 | 11/23-12/2 |
| wi 3b | reinstalls | x42 | 24.00 | 12/11-12/16 |
| wi 4b | powertool | x42 | 78.00 | 11/23-12/2 |
| wi 4b | coatings | x42 | 60.00 | 12/1-12/10 |
| wi 4b | preps/removals | x42 | 16.00 | 11/23-12/2 |
| wi 5 | final inspect | x42 | 2.00 | 12/11-12/16 |
| wi 6 | final inspect | x42 | 2.00 | 12/11-12/16 |
| wi 6 | inspect tanks | x42 | 3.00 | 12-Nov |
| wi 7 | final inspect | x42 | 4.00 | 12/11-12/16 |
| wi 8 | final inspect | x42 | 2.00 | 12/11-12/16 |
| wi 9 | grit blast | x42 | 16.00 | 11/14-11/22 |
| wi 9 | coatings | x42 | 12.00 | 12/1-12/10 |
| wi 9 | preps/removals | x42 | 16.00 | 11/6-11/12 |
| | | Total Hours | 2478.00 | |

**Table A.14 Job Shop X-42 Subtask Breakdown with man-hours and scheduled completion dates.**

Weekends/Holidays

| | 4-Nov | 5-Nov | 6-Nov | 7-Nov | 8-Nov | 9-Nov | 10-Nov | 11-Nov | 12-Nov | 13-Nov | 14-Nov | 15-Nov | 16-Nov | 17-Nov | 18-Nov | 19-Nov | 20-Nov | 21-Nov | 22-Nov | 23-Nov | 24-Nov | 25-Nov | 26-Nov | 27-Nov | 28-Nov |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| x42 total hours/55 days | 0 | 0 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 |
| 2nd avail | | | | | | | | | | | | | | | | | | | | | | | | | |
| total sum | 0 | 0 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 |
| 3rd avail | | | | | | | | | | | | | | | | | | | | | | | | | |
| total sum | 0 | 0 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 |
| Divided by 6 ppd (total hours each person must work) | 0 | 0 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 |

| | 29-Nov | 30-Nov | 1-Dec | 2-Dec | 3-Dec | 4-Dec | 5-Dec | 6-Dec | 7-Dec | 8-Dec | 9-Dec | 10-Dec | 11-Dec | 12-Dec | 13-Dec | 14-Dec | 15-Dec | 16-Dec | 17-Dec | 18-Dec | 19-Dec | 20-Dec | 21-Dec | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| x42 total hours/55 days | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | | |
| 2nd avail | | | 0 | 0 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | | |
| total sum | 45 | 45 | 45 | 45 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | | |
| 3rd avail | | | | | | | | | | | | | | | | | | | | | | | | | |
| total sum | 45 | 45 | 45 | 45 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | | |
| Divided by 6 ppd (total hours each person must work) | 7.5 | 7.5 | 7.5 | 7.5 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | | |

| | 22-Dec | 23-Dec | 24-Dec | 25-Dec | 26-Dec | 27-Dec | 28-Dec | 29-Dec | 30-Dec | 31-Dec | 1-Jan | 2-Jan | 3-Jan | 4-Jan | 5-Jan | 6-Jan | 7-Jan | 8-Jan | 9-Jan | 10-Jan | 11-Jan | 12-Jan | 13-Jan | 14-Jan | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| x42 total hours/55 days | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | | | | | | | | | | | | | | | | |
| 2nd avail | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | |
| total sum | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | |
| 3rd avail | | | | | | | | | | | | | | 0 | 0 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | |
| total sum | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 45 | 45 | 45 | 45 | 45 | 45 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | |
| Divided by 6 ppd (total hours each person must work) | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | |

**Figure A.13 Calendar Schedule Representation of Job Shop X-42 Loading over Three Parallel Availabilities.**

| Work Item # | Description | Job Shop | Man-Hours | Date to Complete |
|---|---|---|---|---|
| wi 9 | preps/removals | x43 | 4.00 | 11/6-11/12 |
| support service per day | | x43 | | |
| support services | | x43 | 81.00 | 1.7 |
| wi 15 | preparation | x43 | 8.00 | 11/6-11/12 |
| wi 16 | install (propeller) | x43 | 20.00 | 12/17-12/29 |
| wi 16 | remove (propeller) | x43 | 20.00 | 11/6-11/12 |
| wi 18 | remove (valve/strainer) | x43 | 16.00 | 11/6-11/12 |
| wi 18 | install (valve/strainers) | x43 | 16.00 | 12/17-12/29 |
| wi 19 | renew rudder asmb | x43 | 14.00 | 12/17-12/29 |
| wi 20 | interferences | x43 | 8.00 | 11/6-11/12 |
| wi 20 | op test final | x43 | 2.00 | 29-Dec |
| wi 20 | remove (stern launch door) | x43 | 20.00 | 11/6-11/12 |
| wi 20 | install (bracing) | x43 | 3.00 | 11/6-11/12 |
| wi 20 | install (stern launch door) | x43 | 30.00 | 18-Dec |
| wi 20 | op test initial | x43 | 3.00 | 5-Nov |
| wi 21 | open tanks | x43 | 2.00 | 5-Nov |
| wi 22 | open tanks | x43 | 2.00 | 5-Nov |
| wi 25 | blast | x43 | 8.00 | 11/14-11/22 |
| wi 25 | preps/removals | x43 | 8.00 | 13-Nov |
| wi 26 | preparation | x43 | 6.00 | 13-Nov |
| wi 26 | reinstalls | x43 | 6.00 | 12/11-12/16 |
| wi 27 | preps/removals | x43 | 20.00 | 11/6-11/12 |
| wi 27 | reinstalls | x43 | 20.00 | 12/11-12/16 |
| wi 28 | coatings | x43 | 9.00 | 12/1-12/10 |
| wi 28 | preps/removals | x43 | 13.00 | 11/6-11/13 |
| wi 28 | reinstalls | x43 | 13.00 | 12/11-12/16 |
| wi 30 | undock vsl | x43 | 45.00 | 30-Dec |
| wi 30 | dry dock vsl | x43 | 45.00 | 6-Nov |
| wi 31 | rigging services | x43 | 96.00 | 2 |
| wi 31 | connect temp services | x43 | 27.00 | 11/6-11/12 |
| wi 31 | final removals | x43 | 18.00 | 12/30-1/14 |
| wi 32 | sea trials | x43 | 27.00 | 1/9-1/13 |
| wi 32 | ride in | x43 | 8.00 | 4-Nov |
| wi 34 | preps/removals | x43 | 4.00 | 11/6-11/13 |
| wi 34 | reinstalls | x43 | 4.00 | 12/11-12/16 |
| wi 36 | pre-docking alignment | x43 | 4.00 | 4-Nov |
| wi 36 | install (shaft asmb) | x43 | 30.00 | 12/17-12/29 |
| wi 36 | protective meas. | x43 | 2.00 | 11/6-11/12 |
| wi 36 | interferences | x43 | 2.00 | 11/6-11/12 |
| wi 36 | remove (shafts) | x43 | 18.00 | 11/6-11/12 |
| wi 3b | remove (towing) | x43 | 6.00 | 11/23-12/2 |
| wi 3b | remove (framing) | x43 | 10.00 | 11/23-12/2 |
| wi 3b | install (towing) | x43 | 6.00 | 12/11-12/16 |
| wi 3b | install (framing) | x43 | 10.00 | 12/11-12/16 |
| wi 3b | remove (electric) | x43 | 4.00 | 11/23-12/2 |
| wi 3b | remove (l/o) | x43 | 6.00 | 11/23-12/2 |
| wi 3b | install (electric) | x43 | 4.00 | 12/11-12/16 |
| wi 3b | install (l/o) | x43 | 6.00 | 12/11-12/16 |
| wi 3b | remove (steering) | x43 | 48.00 | 11/23-12/2 |
| wi 3b | remove (bilge) | x43 | 4.00 | 11/23-12/2 |
| wi 3b | install (steering) | x43 | 48.00 | 12/11-12/16 |
| wi 3b | install (bilge) | x43 | 4.00 | 12/11-12/16 |
| wi 3b | cut access holes | x43 | 12.00 | 11/23-12/2 |
| wi 3b | reinstalls | x43 | 8.00 | 12/11-12/16 |
| wi 4b | reinstalls | x43 | 8.00 | 12/11-12/16 |
| wi 4b | preps/removals | x43 | 8.00 | 11/23-12/2 |
| wi 5 | open tanks | x43 | 2.00 | 5-Nov |
| wi 6 | open tanks | x43 | 2.00 | 5-Nov |
| wi 7 | open tanks | x43 | 4.00 | 5-Nov |
| wi 8 | open tanks | x43 | 2.00 | 5-Nov |
| | | Total Hours | 884.00 | |

**Table A.15 Job Shop X-43 Subtask Breakdown with man-hours and scheduled completion dates.**

| | Availability Start Date | | | | | | Weekends/Holidays | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| X-43 | 4-Nov | 5-Nov | 6-Nov | 7-Nov | 8-Nov | 9-Nov | 10-Nov | 11-Nov | 12-Nov | 13-Nov | 14-Nov | 15-Nov | 16-Nov | 17-Nov | 18-Nov | 19-Nov | 20-Nov | 21-Nov | 22-Nov | 23-Nov | 24-Nov | 25-Nov | 26-Nov | 27-Nov | 28-Nov |
| IBIS | 16 | 21 | 89 | 44 | 0 | 0 | 44 | 0 | 44 | 21 | 5 | 0 | 0 | 5 | 5 | 5 | 5 | 5 | 0 | 0 | 20 | 20 | 20 | 0 | 20 |
| STINGRAY | | | | | | | | | | | | | | | | | | | | | | | | | |
| HAMMERHEAD | | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL MHs | 16 | 21 | 89 | 44 | 0 | 0 | 44 | 0 | 44 | 21 | 5 | 0 | 0 | 5 | 5 | 5 | 5 | 5 | 0 | 0 | 20 | 20 | 20 | 0 | 20 |

| X-43 | 29-Nov | 30-Nov | 1-Dec | 2-Dec | 3-Dec | 4-Dec | 5-Dec | 6-Dec | 7-Dec | 8-Dec | 9-Dec | 10-Dec | 11-Dec | 12-Dec | 13-Dec | 14-Dec | 15-Dec | 16-Dec | 17-Dec | 18-Dec | 19-Dec | 20-Dec | 21-Dec | 22-Dec | 23-Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IBIS | 0 | 0 | 21 | 21 | 4.8 | 4.8 | 4.8 | 0 | 0 | 4.8 | 4.8 | 4.8 | 38 | 38 | 0 | 0 | 38 | 38 | 17 | 17 | 17 | 0 | 0 | 17 | 17 |
| STINGRAY | | | 16 | 21 | 89 | 44 | 0 | 0 | 44 | 0 | 44 | 21 | 5 | 0 | 0 | 5 | 5 | 5 | 5 | 5 | 0 | 0 | 20 | 20 | 20 |
| HAMMERHEAD | | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL MHs | 0 | 0 | 37 | 42 | 94 | 49 | 4.8 | 0 | 44 | 4.8 | 49 | 26 | 43 | 38 | 0 | 5 | 43 | 43 | 22 | 22 | 17 | 0 | 20 | 37 | 37 |

| X-43 | 24-Dec | 25-Dec | 26-Dec | 27-Dec | 28-Dec | 29-Dec | 30-Dec | 31-Dec | 1-Jan | 2-Jan | 3-Jan | 4-Jan | 5-Jan | 6-Jan | 7-Jan | 8-Jan | 9-Jan | 10-Jan | 11-Jan | 12-Jan | 13-Jan | 14-Jan | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IBIS | 17 | 0 | 17 | 0 | 0 | 19 | 50 | 5.3 | 0 | 5.3 | 0 | 0 | 5.3 | 5.3 | 5.3 | 5.3 | 14 | 0 | 0 | 14 | 14 | 5.3 | | | |
| STINGRAY | 20 | | 20 | 0 | | 21 | 21 | 4.8 | 4.8 | 4.8 | 0 | | 4.8 | 4.8 | 4.8 | 38 | 38 | 0 | | 38 | 38 | 17 | | | |
| HAMMERHEAD | | | | | | | | | | | | | 16 | 21 | 89 | 44 | 0 | 0 | 44 | 0 | 44 | 21 | | | |
| TOTAL MHs | 37 | 0 | 37 | 0 | 0 | 41 | 71 | 10 | 4.8 | 10 | 0 | 0 | 26 | 31 | 99 | 87 | 52 | 0 | 44 | 52 | 96 | 44 | | | |

**Figure A.14 Calendar Schedule Representation of Job Shop X-43 Loading over Three Parallel Availabilities.**

| Work Item # | Description | Job Shop | Man-Hours | Date to Complete |
|---|---|---|---|---|
| wi 1 | contractor | x61 | 2.00 | 23-Nov |
| wi 21 | contractor | x61 | 2.00 | 11/5-11/12 |
| wi 22 | contractor | x61 | 2.00 | 11/5-11/12 |
| wi 25 | preps/removals | x61 | 4.00 | 11/13-11/22 |
| wi 26 | preparation | x61 | 6.00 | 11/13-11/22 |
| wi 28 | preps/removals | x61 | 6.00 | 11/13-11/22 |
| wi 34 | jet blast | x61 | 4.00 | 14-Nov |
| wi 3a | contractor | x61 | 2.00 | 11/5-11/12 |
| wi 4a | contractor | x61 | 2.00 | 11/5-11/12 |
| wi 4b | preps/removals | x61 | 2.00 | 11/5-11/12 |
| wi 5 | contractor | x61 | 2.00 | 11/6-11/12 |
| wi 6 | contractor | x61 | 2.00 | 11/6-11/12 |
| wi 7 | contractor | x61 | 4.00 | 11/6-11/12 |
| wi 8 | contractor | x61 | 4.00 | 11/6-11/12 |
| wi 30 | undock vsl | x64 | 8.00 | 30-Dec |
| wi 30 | dry dock vsl | x64 | 8.00 | 6-Nov |
| wi 36 | major misalignment | x64 | 16.00 | 11/13-12/2 |
| wi 36 | major misalignment | x65 | 16.00 | 11/13-12/2 |
| wi 36 | major misalignment | x66 | 16.00 | 11/13-12/2 |
| | | Total Hours | 108.00 | |

Table A.16 Job Shops X-61-66 Subtask Breakdown with man-hours and scheduled completion dates.

Availability Start Date | Weekends/Holidays

| X-61 | 4-Nov | 5-Nov | 6-Nov | 7-Nov | 8-Nov | 9-Nov | 10-Nov | 11-Nov | 12-Nov | 13-Nov | 14-Nov | 15-Nov | 16-Nov | 17-Nov | 18-Nov | 19-Nov | 20-Nov | 21-Nov | 22-Nov | 23-Nov | 24-Nov | 25-Nov | 26-Nov | 27-Nov | 28-Nov |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IBIS | | 2.5 | 5.5 | 5.5 | | | 5.5 | | 3 | 2.3 | 6.3 | | | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | | 2 | | | | | |
| STINGRAY | | | | | | | | | | | | | | | | | | | | | | | | | |
| HAMMERHEAD | | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL MHs | 0 | 2.5 | 5.5 | 5.5 | 0 | 0 | 5.5 | 0 | 3 | 2.3 | 6.3 | 0 | 0 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |

| X-61 | 29-Nov | 30-Nov | 1-Dec | 2-Dec | 3-Dec | 4-Dec | 5-Dec | 6-Dec | 7-Dec | 8-Dec | 9-Dec | 10-Dec | 11-Dec | 12-Dec | 13-Dec | 14-Dec | 15-Dec | 16-Dec | 17-Dec | 18-Dec | 19-Dec | 20-Dec | 21-Dec | 22-Dec | 23-Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IBIS | | | | | | | | | | | | | | | | | | | | | | | | | |
| STINGRAY | | | | 2.5 | 5.5 | 5.5 | | | 5.5 | | 3 | 2.3 | 6.3 | | | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | | 2 | | | |
| HAMMERHEAD | | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL MHs | 0 | 0 | 0 | 2.5 | 5.5 | 5.5 | 0 | 0 | 5.5 | 0 | 3 | 2.3 | 6.3 | 0 | 0 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 0 | 2 | 0 | 0 | 0 |

| X-61 | 24-Dec | 25-Dec | 26-Dec | 27-Dec | 28-Dec | 29-Dec | 30-Dec | 31-Dec | 1-Jan | 2-Jan | 3-Jan | 4-Jan | 5-Jan | 6-Jan | 7-Jan | 8-Jan | 9-Jan | 10-Jan | 11-Jan | 12-Jan | 13-Jan | 14-Jan | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IBIS | | | | | | | | | | | | | | | | | | | | | | | | | |
| STINGRAY | | | | | | | | | | | | | | | | | | | | | | | | | |
| HAMMERHEAD | | | | | | | | | | | | | | 2.5 | 5.5 | 5.5 | | | 5.5 | | 3 | 2.3 | | | |
| TOTAL MHs | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2.5 | 5.5 | 5.5 | 0 | 0 | 5.5 | 0 | 3 | 2.3 | | | |

Figure A.15 Calendar Schedule Representation of Job Shop X-61 Loading over Three Parallel Availabilities.

| | Availability Start Date | | | | | | Weekends/Holidays | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| X-64 | 4-Nov | 5-Nov | 6-Nov | 7-Nov | 8-Nov | 9-Nov | 10-Nov | 11-Nov | 12-Nov | 13-Nov | 14-Nov | 15-Nov | 16-Nov | 17-Nov | 18-Nov | 19-Nov | 20-Nov | 21-Nov | 22-Nov | 23-Nov | 24-Nov | 25-Nov | 26-Nov | 27-Nov | 28-Nov |
| IBIS | | | 8 | | | | | | | 1.2 | 1.2 | | | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | | | 1.2 | 1.2 | 1.2 | | 1.2 |
| STINGRAY | | | | | | | | | | | | | | | | | | | | | | | | | |
| HAMMERHEAD | | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL MHs | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 1.2 | 1.2 | 0 | 0 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 0 | 0 | 1.2 | 1.2 | 1.2 | 0 | 1.2 |
| X-64 | 29-Nov | 30-Nov | 1-Dec | 2-Dec | 3-Dec | 4-Dec | 5-Dec | 6-Dec | 7-Dec | 8-Dec | 9-Dec | 10-Dec | 11-Dec | 12-Dec | 13-Dec | 14-Dec | 15-Dec | 16-Dec | 17-Dec | 18-Dec | 19-Dec | 20-Dec | 21-Dec | 22-Dec | 23-Dec |
| IBIS | | | 1.2 | 1.2 | | | | | | | | | | | | | | | | | | | | | |
| STINGRAY | | | | | 8 | | | | | | | 1.2 | 1.2 | | | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | | | 1.2 | 1.2 | 1.2 |
| HAMMERHEAD | | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL MHs | 0 | 0 | 1.2 | 1.2 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 1.2 | 1.2 | 0 | 0 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 0 | 0 | 1.2 | 1.2 | 1.2 |
| X-64 | 24-Dec | 25-Dec | 26-Dec | 27-Dec | 28-Dec | 29-Dec | 30-Dec | 31-Dec | 1-Jan | 2-Jan | 3-Jan | 4-Jan | 5-Jan | 6-Jan | 7-Jan | 8-Jan | 9-Jan | 10-Jan | 11-Jan | 12-Jan | 13-Jan | 14-Jan | | | |
| IBIS | | | | | | | | 8 | | | | | | | | | | | | | | | | | |
| STINGRAY | 1.2 | | 1.2 | | | 1.2 | 1.2 | | | | | | | | | | | | | | | | | | |
| HAMMERHEAD | | | | | | | | | | | | | | | 8 | | | | | | | 1.2 | | | |
| TOTAL MHs | 1.2 | 0 | 1.2 | 0 | 0 | 1.2 | 1.2 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 1.2 | | | |

**Figure A.16 Calendar Schedule Representation of Job Shop X-64 Loading over Three Parallel Availabilities.**

| | Availability Start Date | | | | | | Weekends/Holidays | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| X-65 | 4-Nov | 5-Nov | 6-Nov | 7-Nov | 8-Nov | 9-Nov | 10-Nov | 11-Nov | 12-Nov | 13-Nov | 14-Nov | 15-Nov | 16-Nov | 17-Nov | 18-Nov | 19-Nov | 20-Nov | 21-Nov | 22-Nov | 23-Nov | 24-Nov | 25-Nov | 26-Nov | 27-Nov | 28-Nov |
| IBIS | | | | | | | | | | 1.2 | 1.2 | | | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | | | 1.2 | 1.2 | 1.2 | | 1.2 |
| STINGRAY | | | | | | | | | | | | | | | | | | | | | | | | | |
| HAMMERHEAD | | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL MHs | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.2 | 1.2 | 0 | 0 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 0 | 0 | 1.2 | 1.2 | 1.2 | 0 | 1.2 |
| X-65 | 29-Nov | 30-Nov | 1-Dec | 2-Dec | 3-Dec | 4-Dec | 5-Dec | 6-Dec | 7-Dec | 8-Dec | 9-Dec | 10-Dec | 11-Dec | 12-Dec | 13-Dec | 14-Dec | 15-Dec | 16-Dec | 17-Dec | 18-Dec | 19-Dec | 20-Dec | 21-Dec | 22-Dec | 23-Dec |
| IBIS | | | 1.2 | 1.2 | | | | | | | | | | | | | | | | | | | | | |
| STINGRAY | | | | | | | | | | | | 1.2 | 1.2 | | | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | | | 1.2 | 1.2 | 1.2 |
| HAMMERHEAD | | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL MHs | 0 | 0 | 1.2 | 1.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.2 | 1.2 | 0 | 0 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 0 | 0 | 1.2 | 1.2 | 1.2 |
| X-65 | 24-Dec | 25-Dec | 26-Dec | 27-Dec | 28-Dec | 29-Dec | 30-Dec | 31-Dec | 1-Jan | 2-Jan | 3-Jan | 4-Jan | 5-Jan | 6-Jan | 7-Jan | 8-Jan | 9-Jan | 10-Jan | 11-Jan | 12-Jan | 13-Jan | 14-Jan | | | |
| IBIS | | | | | | | | | | | | | | | | | | | | | | | | | |
| STINGRAY | 1.2 | | 1.2 | | | 1.2 | 1.2 | | | | | | | | | | | | | | | | | | |
| HAMMERHEAD | | | | | | | | | | | | | | | | | | | | | | 1.2 | | | |
| TOTAL MHs | 1.2 | 0 | 1.2 | 0 | 0 | 1.2 | 1.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.2 | | | |

**Figure A.17 Calendar Schedule Representation of Job Shop X-65 Loading over Three Parallel Availabilities.**

Availability Start Date | Weekends/Holidays

| X-66 | 4-Nov | 5-Nov | 6-Nov | 7-Nov | 8-Nov | 9-Nov | 10-Nov | 11-Nov | 12-Nov | 13-Nov | 14-Nov | 15-Nov | 16-Nov | 17-Nov | 18-Nov | 19-Nov | 20-Nov | 21-Nov | 22-Nov | 23-Nov | 24-Nov | 25-Nov | 26-Nov | 27-Nov | 28-Nov |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IBIS | | | | | | | | | | 1.2 | 1.2 | | | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | | | 1.2 | 1.2 | 1.2 | | 1.2 |
| STINGRAY | | | | | | | | | | | | | | | | | | | | | | | | | |
| HAMMERHEAD | | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL MHs | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.2 | 1.2 | 0 | 0 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 0 | 0 | 1.2 | 1.2 | 1.2 | 0 | 1.2 |

| X-66 | 29-Nov | 30-Nov | 1-Dec | 2-Dec | 3-Dec | 4-Dec | 5-Dec | 6-Dec | 7-Dec | 8-Dec | 9-Dec | 10-Dec | 11-Dec | 12-Dec | 13-Dec | 14-Dec | 15-Dec | 16-Dec | 17-Dec | 18-Dec | 19-Dec | 20-Dec | 21-Dec | 22-Dec | 23-Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IBIS | | | 1.2 | 1.2 | | | | | | | | | | | | | | | | | | | | | |
| STINGRAY | | | | | | | | | | | | 1.2 | 1.2 | | | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | | | 1.2 | 1.2 | 1.2 |
| HAMMERHEAD | | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL MHs | 0 | 0 | 1.2 | 1.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.2 | 1.2 | 0 | 0 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 0 | 0 | 1.2 | 1.2 | 1.2 |

| X-66 | 24-Dec | 25-Dec | 26-Dec | 27-Dec | 28-Dec | 29-Dec | 30-Dec | 31-Dec | 1-Jan | 2-Jan | 3-Jan | 4-Jan | 5-Jan | 6-Jan | 7-Jan | 8-Jan | 9-Jan | 10-Jan | 11-Jan | 12-Jan | 13-Jan | 14-Jan | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IBIS | | | | | | | | | | | | | | | | | | | | | | | | | |
| STINGRAY | | 1.2 | | | 1.2 | 1.2 | | | | | | | | | | | | | | | | | | | |
| HAMMERHEAD | | | | | | | | | | | | | | | | | | | | | | 1.2 | | | |
| TOTAL MHs | 0 | 1.2 | 0 | 0 | 1.2 | 1.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.2 | | | |

**Figure A.18 Calendar Schedule Representation of Job Shop X-66 Loading over Three Parallel Availabilities.**

ONE AVAILABILITY ONLY

Weekends/Holidays | CGC IBIS

| | 4-Nov | 5-Nov | 6-Nov | 7-Nov | 8-Nov | 9-Nov | 10-Nov | 11-Nov | 12-Nov | 13-Nov | 14-Nov | 15-Nov | 16-Nov | 17-Nov | 18-Nov | 19-Nov | 20-Nov | 21-Nov | 22-Nov | 23-Nov | 24-Nov | 25-Nov | 26-Nov | 27-Nov | 28-Nov |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total | 70.8 | 132 | 443 | 262.5 | 45.1 | 45.1 | 258.6 | 45.1 | 331.6 | 204.9 | 109 | 45.1 | 45.1 | 107 | 107 | 107 | 105 | 97 | 45.1 | 45.1 | 181.1 | 179.1 | 179.1 | 45.1 | 179.1 |
| /25 ppd | 2.821 | 5.25 | 17.6 | 10.46 | 7.52 | 7.517 | 10.3 | 7.52 | 13.21 | 8.163 | 4.32 | 7.52 | 7.52 | 4.24 | 4.24 | 4.24 | 4.16 | 3.8 | 7.52 | 7.52 | 7.216 | 7.136 | 7.136 | 7.52 | 7.136 |
| /22.2ppd | 3.189 | 5.94 | 19.9 | 11.82 | 7.52 | 7.517 | 11.65 | 7.52 | 14.93 | 9.23 | 4.89 | 7.52 | 7.52 | 4.8 | 4.8 | 4.8 | 4.71 | 4.3 | 7.52 | 7.52 | 8.158 | 8.068 | 8.068 | 7.52 | 8.068 |

| | 29-Nov | 30-Nov | 1-Dec | 2-Dec | 3-Dec | 4-Dec | 5-Dec | 6-Dec | 7-Dec | 8-Dec | 9-Dec | 10-Dec | 11-Dec | 12-Dec | 13-Dec | 14-Dec | 15-Dec | 16-Dec | 17-Dec | 18-Dec | 19-Dec | 20-Dec | 21-Dec | 22-Dec | 23-Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total | 0 | 0 | 24.7 | 80.99 | 53.4 | 53.39 | 53.39 | 45.1 | 45.1 | 53.39 | 53.4 | 82.2 | 342 | 342 | 45.1 | 45.1 | 348 | 333 | 140 | 157 | 129.1 | 45.1 | 45.1 | 130 | 129.1 |
| /25 ppd | 0 | 0 | 0.99 | 3.226 | 2.13 | 2.127 | 2.127 | 7.52 | 7.517 | 2.127 | 2.13 | 3.27 | 13.6 | 13.6 | 7.52 | 7.52 | 13.9 | 13 | 5.59 | 6.26 | 5.145 | 7.517 | 7.517 | 5.18 | 5.145 |
| /22.2ppd | 0 | 0 | 1.11 | 3.648 | 2.4 | 2.405 | 2.405 | 7.52 | 7.517 | 2.405 | 2.4 | 3.7 | 15.4 | 15.4 | 7.52 | 7.52 | 15.7 | 15 | 6.33 | 7.08 | 5.817 | 7.517 | 7.517 | 5.86 | 5.817 |

| | 24-Dec | 25-Dec | 26-Dec | 27-Dec | 28-Dec | 29-Dec | 30-Dec | 31-Dec | 1-Jan | 2-Jan | 3-Jan | 4-Jan | 5-Jan | 6-Jan | 7-Jan | 8-Jan | 9-Jan | 10-Jan | 11-Jan | 12-Jan | 13-Jan | 14-Jan |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total | 129.1 | 45.1 | 137 | 45.1 | 45.1 | 149.4 | 172.5 | 111 | 0 | 92.88 | 0 | 0 | 72.9 | 68.9 | 68.9 | 77.6 | 96.6 | 0 | 0 | 87.6 | 101.9 | 9.44 |
| /25 ppd | 5.145 | 7.52 | 5.46 | 7.517 | 7.52 | 5.953 | 6.874 | 4.42 | 0 | 3.7 | 0 | 0 | 2.9 | 2.74 | 2.74 | 3.09 | 3.85 | 0 | 0 | 3.49 | 4.059 | 0.376 |
| /22.2ppd | 5.817 | 7.52 | 6.18 | 7.517 | 7.52 | 6.731 | 7.772 | 4.99 | 0 | 4.184 | 0 | 0 | 3.28 | 3.1 | 3.1 | 3.49 | 4.35 | 0 | 0 | 3.94 | 4.589 | 0.425 |

**Figure A.19 Loading of one project with all job shop man-hours combined.**

TWO AVAILABILITIES — Weekends/Holidays | CGC IBIS | CGC IBIS & CGC STINGRAY

| | 4-Nov | 5-Nov | 6-Nov | 7-Nov | 8-Nov | 9-Nov | 10-Nov | 11-Nov | 12-Nov | 13-Nov | 14-Nov | 15-Nov | 16-Nov | 17-Nov | 18-Nov | 19-Nov | 20-Nov | 21-Nov | 22-Nov | 23-Nov | 24-Nov | 25-Nov | 26-Nov | 27-Nov | 28-Nov |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total | 70.8 | 131.8 | 442.6 | 252.0 | 45.1 | 45.1 | 258.6 | 45.1 | 342.1 | 204.9 | 108.5 | 45.1 | 45.1 | 106.5 | 106.5 | 106.5 | 104.5 | 96.5 | 45.1 | 47.1 | 179.1 | 179.1 | 179.1 | 45.1 | 181.1 |
| /25 ppd | 2.8 | 5.3 | 17.6 | 10.0 | 7.5 | 7.5 | 10.3 | 7.5 | 13.6 | 8.2 | 4.3 | 7.5 | 7.5 | 4.2 | 4.2 | 4.2 | 4.2 | 3.8 | 7.5 | 7.9 | 7.1 | 7.1 | 7.1 | 7.5 | 7.2 |
| /22.2ppd | 3.2 | 5.9 | 19.9 | 11.4 | 7.5 | 7.5 | 11.6 | 7.5 | 15.4 | 9.2 | 4.9 | 7.5 | 7.5 | 4.8 | 4.8 | 4.8 | 4.7 | 4.3 | 7.5 | 7.9 | 8.1 | 8.1 | 8.1 | 7.5 | 8.2 |

| | 29-Nov | 30-Nov | 1-Dec | 2-Dec | 3-Dec | 4-Dec | 5-Dec | 6-Dec | 7-Dec | 8-Dec | 9-Dec | 10-Dec | 11-Dec | 12-Dec | 13-Dec | 14-Dec | 15-Dec | 16-Dec | 17-Dec | 18-Dec | 19-Dec | 20-Dec | 21-Dec | 22-Dec | 23-Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total | 45.1 | 45.1 | 264.6 | 316.8 | 487.6 | 334.2 | 257.0 | 90.2 | 90.2 | 207.1 | 396.2 | 298.8 | 455.1 | 448.7 | 90.2 | 90.2 | 454.7 | 439.9 | 235.0 | 207.4 | 226.6 | 90.2 | 90.2 | 311.2 | 308.2 |
| /25 ppd | 7.5 | 7.5 | 10.5 | 12.6 | 19.4 | 13.3 | 10.2 | 15.0 | 15.0 | 8.3 | 15.8 | 11.9 | 18.1 | 17.9 | 15.0 | 15.0 | 18.1 | 17.5 | 9.4 | 8.3 | 9.0 | 15.0 | 15.0 | 12.4 | 12.3 |
| /22.2ppd | 7.5 | 7.5 | 11.9 | 14.3 | 22.0 | 15.1 | 11.6 | 15.0 | 15.0 | 9.3 | 17.8 | 13.5 | 20.5 | 20.2 | 15.0 | 15.0 | 20.5 | 19.8 | 10.6 | 9.3 | 10.2 | 15.0 | 15.0 | 14.0 | 13.9 |

| | 24-Dec | 25-Dec | 26-Dec | 27-Dec | 28-Dec | 29-Dec | 30-Dec | 31-Dec | 1-Jan | 2-Jan | 3-Jan | 4-Jan | 5-Jan | 6-Jan | 7-Jan | 8-Jan | 9-Jan | 10-Jan | 11-Jan | 12-Jan | 13-Jan | 14-Jan |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total | 302.5 | 90.2 | 316.2 | 90.2 | 90.2 | 345.3 | 348.3 | 185.5 | 45.1 | 188.3 | 45.1 | 45.1 | 155.1 | 151.1 | 203.8 | 419.7 | 429.9 | 45.1 | 45.1 | 427.2 | 389.9 | 155.9 |
| /25 ppd | 12.1 | 15.0 | 12.6 | 15.0 | 15.0 | 13.8 | 13.9 | 7.4 | 7.5 | 7.5 | 7.5 | 7.5 | 6.2 | 6.0 | 8.1 | 16.7 | 17.1 | 7.5 | 7.5 | 17.0 | 15.5 | 6.2 |
| /22.2ppd | 13.6 | 15.0 | 14.2 | 15.0 | 15.0 | 15.6 | 15.7 | 8.4 | 7.5 | 8.5 | 7.5 | 7.5 | 7.0 | 6.8 | 9.2 | 18.9 | 19.4 | 7.5 | 7.5 | 19.2 | 17.6 | 7.0 |

**Figure A.20 Loading of two parallel projects with all job shop man-hours combined.**

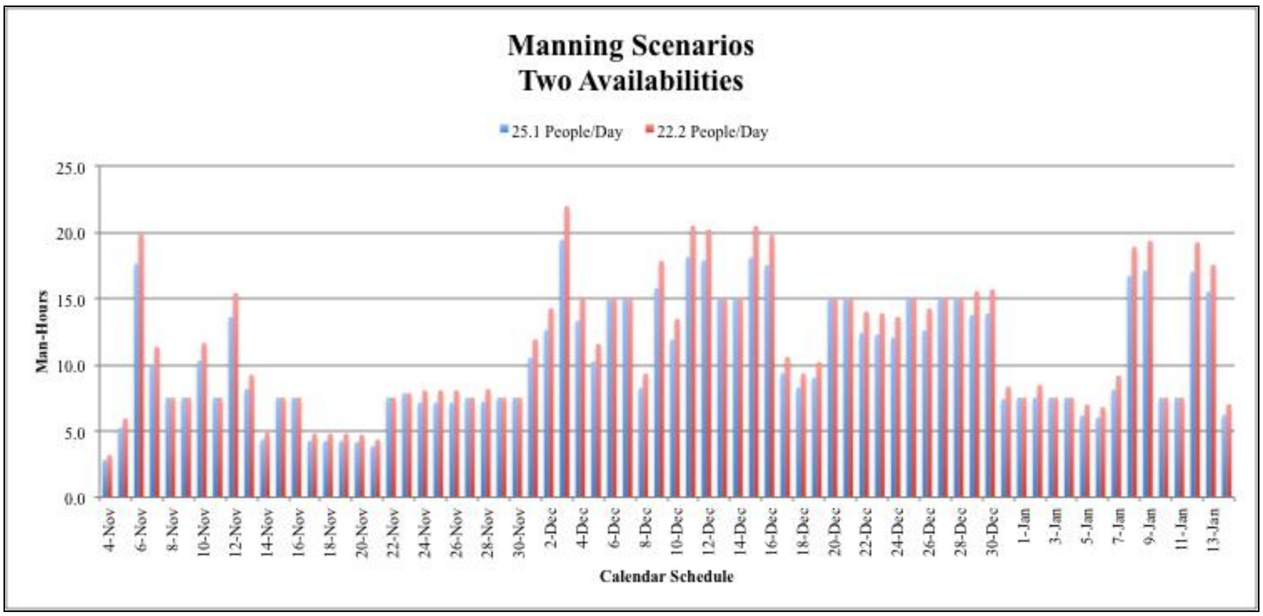


**Figure A.21 Manning Scenario Comparative Graph for Two Availabilities.**

**THREE AVAILABILITIES**

Weekends/Holidays | CGC IBIS | CGC IBIS & CGC STINGRAY | CGC IBIS,CGC STINGRAY, & CGC HAMMERHEAD

| | 4-Nov | 5-Nov | 6-Nov | 7-Nov | 8-Nov | 9-Nov | 10-Nov | 11-Nov | 12-Nov | 13-Nov | 14-Nov | 15-Nov | 16-Nov | 17-Nov | 18-Nov | 19-Nov | 20-Nov | 21-Nov | 22-Nov | 23-Nov | 24-Nov | 25-Nov | 26-Nov | 27-Nov | 28-Nov |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total | 70.8 | 131.8 | 442.6 | 262.5 | 45.1 | 45.1 | 258.6 | 45.1 | 331.6 | 204.9 | 108.5 | 45.1 | 45.1 | 106.5 | 106.5 | 106.5 | 104.5 | 96.5 | 45.1 | 47.1 | 179.1 | 179.1 | 179.1 | 45.1 | 181.1 |
| /25 ppd | 2.8 | 5.3 | 17.6 | 10.5 | 7.5 | 7.5 | 10.3 | 7.5 | 13.2 | 8.2 | 4.3 | 7.5 | 7.5 | 4.2 | 4.2 | 4.2 | 4.2 | 3.8 | 7.5 | 7.9 | 7.1 | 7.1 | 7.1 | 7.5 | 7.2 |
| /22.2ppd | 3.2 | 5.9 | 19.9 | 11.8 | 7.5 | 7.5 | 11.6 | 7.5 | 14.9 | 9.2 | 4.9 | 7.5 | 7.5 | 4.8 | 4.8 | 4.8 | 4.7 | 4.3 | 7.5 | 7.9 | 8.1 | 8.1 | 8.1 | 7.5 | 8.2 |

| | 29-Nov | 30-Nov | 1-Dec | 2-Dec | 3-Dec | 4-Dec | 5-Dec | 6-Dec | 7-Dec | 8-Dec | 9-Dec | 10-Dec | 11-Dec | 12-Dec | 13-Dec | 14-Dec | 15-Dec | 16-Dec | 17-Dec | 18-Dec | 19-Dec | 20-Dec | 21-Dec | 22-Dec | 23-Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total | 45.1 | 45.1 | 264.6 | 316.8 | 487.6 | 334.2 | 257.0 | 90.2 | 90.2 | 207.1 | 396.2 | 298.8 | 455.1 | 448.7 | 90.2 | 90.2 | 454.7 | 439.9 | 235.0 | 207.4 | 226.6 | 90.2 | 90.2 | 311.2 | 308.2 |
| /25 ppd | 7.5 | 7.5 | 10.5 | 12.6 | 19.4 | 13.3 | 10.2 | 15.0 | 15.0 | 8.3 | 15.8 | 11.9 | 18.1 | 17.9 | 15.0 | 15.0 | 18.1 | 17.5 | 9.4 | 8.3 | 9.0 | 15.0 | 15.0 | 12.4 | 12.3 |
| /22.2ppd | 7.5 | 7.5 | 11.9 | 14.3 | 22.0 | 15.1 | 11.6 | 15.0 | 15.0 | 9.3 | 17.8 | 13.5 | 20.5 | 20.2 | 15.0 | 15.0 | 20.5 | 19.8 | 10.6 | 9.3 | 10.2 | 15.0 | 15.0 | 14.0 | 13.9 |

| | 24-Dec | 25-Dec | 26-Dec | 27-Dec | 28-Dec | 29-Dec | 30-Dec | 31-Dec | 1-Jan | 2-Jan | 3-Jan | 4-Jan | 5-Jan | 6-Jan | 7-Jan | 8-Jan | 9-Jan | 10-Jan | 11-Jan | 12-Jan | 13-Jan | 14-Jan |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total | 308.2 | 90.2 | 316.2 | 90.2 | 90.2 | 339.6 | 348.3 | 185.0 | 46.0 | 189.9 | 45.1 | 45.1 | 240.4 | 326.0 | 635.8 | 667.7 | 585.3 | 90.2 | 90.2 | 576.7 | 739.9 | 350.8 |
| /25 ppd | 12.3 | 15.0 | 12.6 | 15.0 | 15.0 | 13.5 | 13.9 | 7.4 | 7.7 | 7.6 | 7.5 | 7.5 | 9.6 | 13.0 | 25.3 | 26.6 | 23.3 | 15.0 | 15.0 | 23.0 | 29.5 | 14.0 |
| /22.2ppd | 13.9 | 15.0 | 14.2 | 15.0 | 15.0 | 15.3 | 15.7 | 8.3 | 7.7 | 8.6 | 7.5 | 7.5 | 10.8 | 14.7 | 28.6 | 30.1 | 26.4 | 15.0 | 15.0 | 26.0 | 33.3 | 15.8 |

**Figure A.22 Loading of three parallel projects with all job shop man-hours combined.**

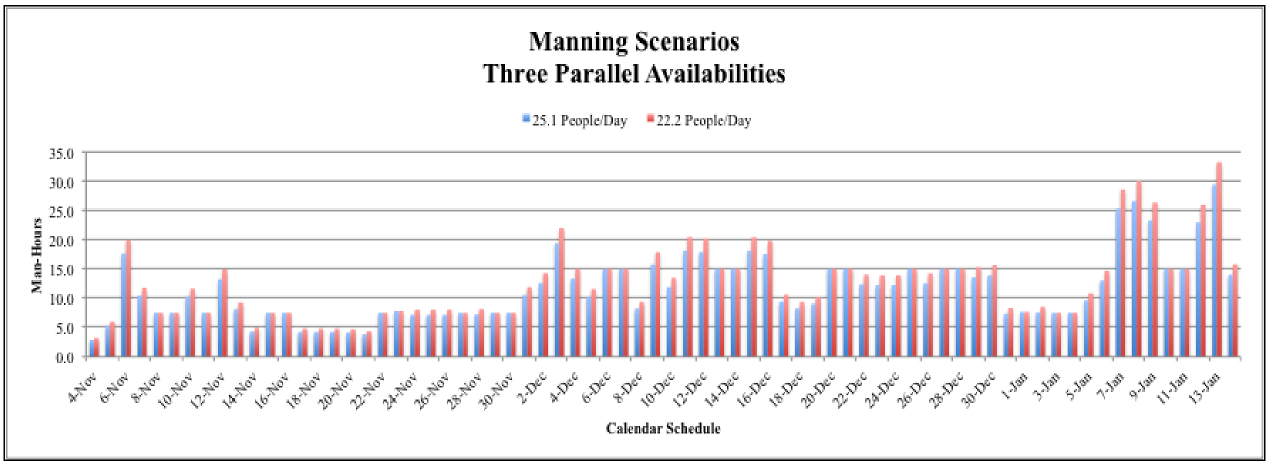


**Figure A.23 Manning Scenario Comparative Graph for Three Availabilities.**

| POMPANO WBS | | | | | | |
|---|---|---|---|---|---|---|
| **Monday 3/2** | **Tues 3/3 - Wed 3/4** | **Thurs 3/5-COB Wed3/11** | **Thu 3/12- COB 3/20** | **Sat 3/21- Sun 3/22** | **Mon 3/23 - Wed 4/1** | **Thu 4/2-Sun 4/12** |
| Ride in and Pre-op Test | Measures propulsion shaft shims and pre-docking propulsion shaft hub | **Drydock Cutter / Seal Enclosure Install Temp Services 3/5** | 100% Blast hull, Stern tubes, Laz, s/s & Prime Hull for side scan | Commence Side Scan | Gray Water & Sewage Pipe Flush | Prime & Paint Cutter |
| coil up cables, protect coiled up cables | Remove liquid loads (CTR) | Marine Chemist/ Gas Free Cert. | Blue Fit Props | | Prep Eng Room for substrate inspection | Capastic Fairing |
| | Pull TLIs | Remove Sea Valves & Speed Log Valve | Prep Sea Valves for Install | | Install Shaft bearings | All Hotwork |
| | Oil, Waste Oil, and Grey Water Tanks | appendages Rudders/Shafts/Props | Complete Mast Mods | | Perform UT shots | |
| | Remove HPU | Remove Notch Pads | Tech Rep - shaft seals | | | |
| | Remove Small Boat | Mobilize Blast Equipment | Remove grit from floor of enclosure (CTR) | | | |
| | Remove Mast | Optical Alignment | | | | |
| | | Remove Bilge and Lazarette interferences | | | | |
| | | Remove Stern Door | | | | |
| **Mon 4/13-Sun 4/19** | **Mon 4/20- Fri 4/24** | **Sat 4/25- Wed 4/29** | **Thurs 4/30** | **Fri 5/1** | **Mon 5/4-Tues 5/5** | **Wed 5/6** |
| Install Interferences | **** 4/23- Open Structure for mast install**** | Elex Testing | ***4/30 Undock Vessel*** | Take Final Face Readings | Sea Trials | Final Walk-Thru |
| Load Sea Valves | Install Mast | Clean Vessel (CTR) | Boom/Refuel Vessel | Crew arrives | | Cutter Departs |
| Notify crew of report date | Install stern gate | Final touch-ups | Fill P/W Tanks | Outfit Onload | | |
| Install Hull Zincs | Tech Rep - shaft seals | | Install Lagging | Dock Trials | | |
| Lay Deck Pads | Install U/W Appendages | | Load Small Boat | | | |
| Install Sea Valves and Speed Log Valve | | | | | | |
| Shaft Seal Piping Install | | | | | | |
| Paint ER Bilge & Lazarette | | | | | | |
| Comparisons to BIS WBS | Pushed Back (Later Date) | Pushed Up (Earlier Date) | New Item on WBS | | | |

**Figure A.24 Color Coded WBS for CGC POMPANO.**